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Science 30

MODULE 2

Patterns of Heredity

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Science 30

Module 2

Patterns of Heredity

Alberta
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Science 30
Student Module Booklet
Module 2
Patterns of Heredity
Alberta Distance Learning Centre
ISBN 0-7741-1138-0

Cover Photo: Courtesy of Gane Olsen

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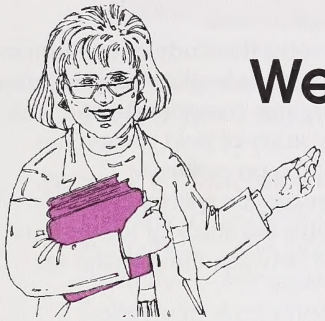


Welcome to Module 2!

We hope you'll enjoy your study of Patterns of Heredity.

To make your learning a bit easier, watch the referenced videocassettes whenever you see this icon.

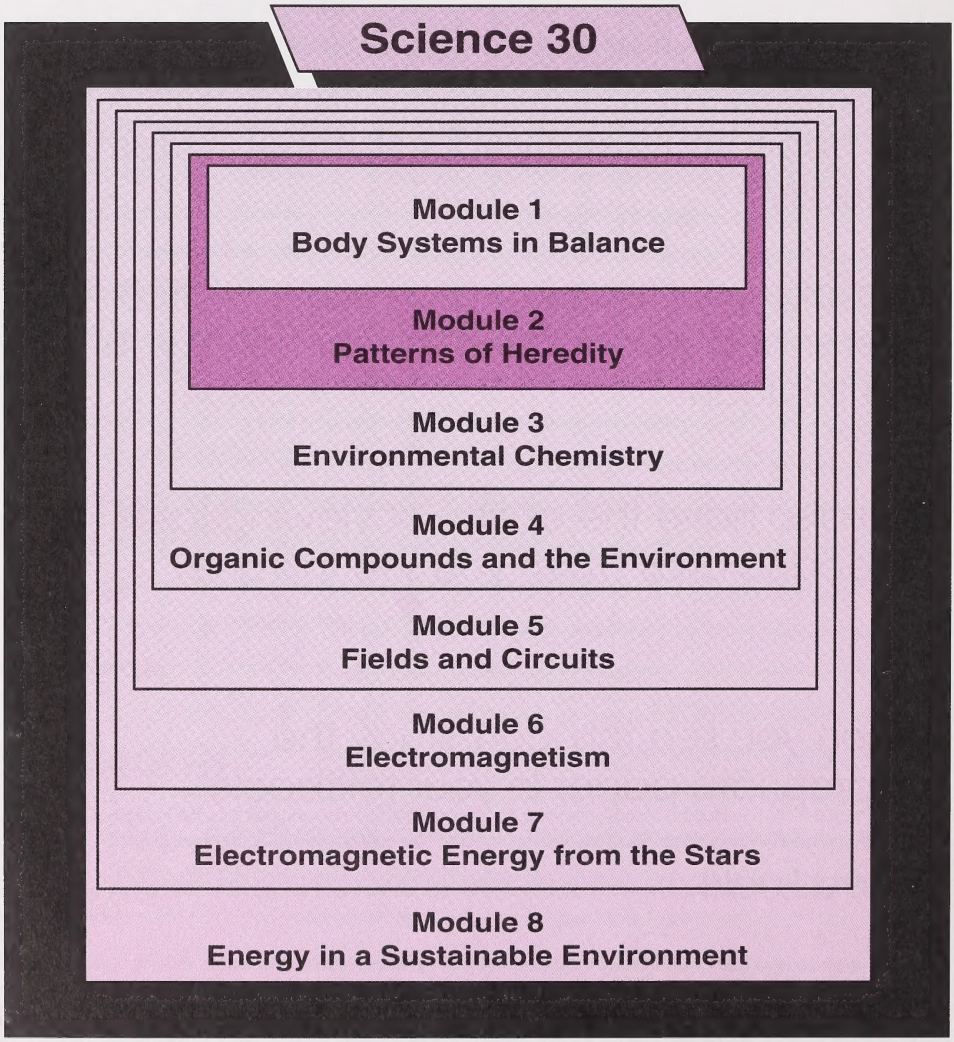
You also have the option of viewing laser videodisc clips when you see this one.

When you see this icon, study the appropriate pages in your textbook.

Good Luck!

Course Overview

This course contains eight modules. Modules 1 and 2 involve the study of the human circulatory system, defence mechanisms, the nervous system, as well as the principles of genetics. Modules 3 and 4 investigate acids and bases, organic compounds, and their effects on the environment. Modules 5 and 6 involve the study of field theory, the operation of various electrical devices, as well as some of the properties of electromagnetic waves. Module 7 focuses on the electromagnetic spectrum and its relation to the study of the Universe. Module 8 will involve the study of the various sources of energy and how a balance must be maintained between the demand for energy and the need to maintain a viable environment.



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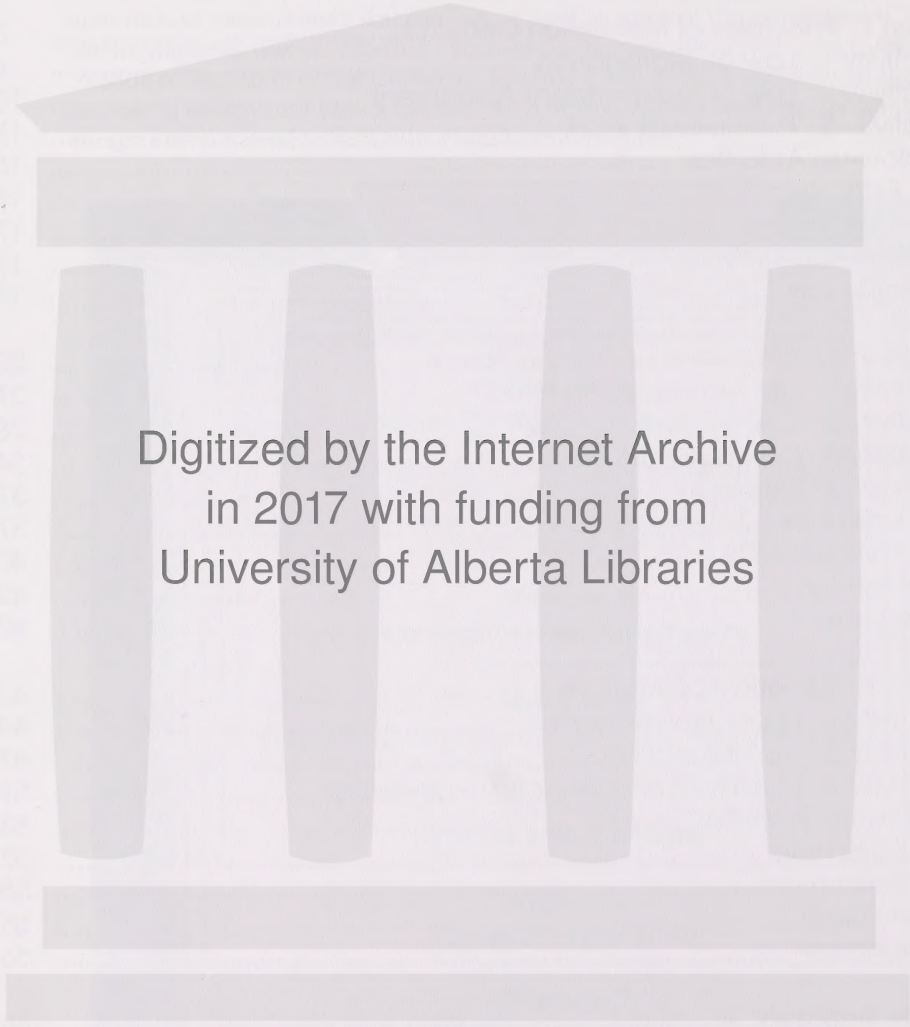
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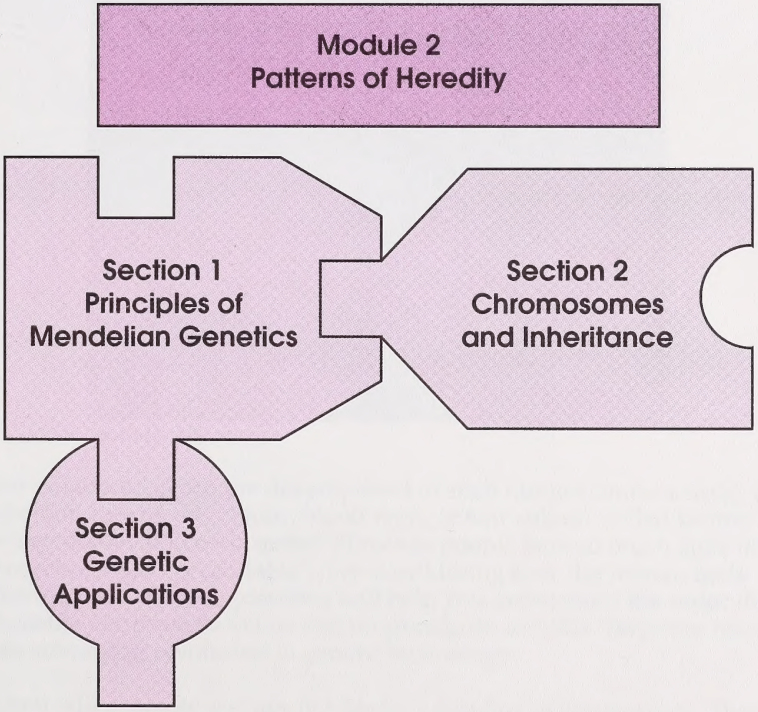
MODULE OVERVIEW

"You are what you eat!" announced the health food fanatic while glaring at the junk food addict. "No, no, no!" exclaimed the body builder. "My body can become what I want it to be by strenuous exercise." Finally, the science whiz entered the classroom discussion. "Our traits are simply the products of our parents, and their parents, and their parents, and so on."

Does this sound familiar? Maybe you have heard the first two opinions before, but what about the third? The influence of heredity may seem obvious, but the patterns for transmitting traits from one generation to the next are quite complex, yet highly interesting.

What you are and what you may become is influenced directly by your genetic code. Even diseases or disorders can have their origin in the traits you inherited from your parents.

In this module you will first establish the principles of classical genetics. Then, you will apply these mechanisms to the inheritance of traits from parents. Finally, some analysis of genetics in populations and new technologies dealing with genetics will be done.



Evaluation

Your mark in this module will be determined by how well you complete the assignments at the end of each section. You must complete all assignments. In this module, you are expected to complete three section assignments. The mark distribution is as follows:

Section 1 Assignment	**30 marks**
Section 2 Assignment	**40 marks**
Section 3 Assignment	**30 marks**
TOTAL	**100 marks**

Section

1 Principles of Mendelian Genetics

JIM WHITMER PHOTOGRAPHY

Have you ever wondered about the development of such human characteristics as gender, skin colour, height, eye colour, blood type, or hair colour? What factors influence the expression of genetic traits? How can people look so much alike or so different? Are some events predictable when considering how the human body develops? The answers to these questions will help you understand the order that exists in nature. Probable occurrences follow certain principles and this discovery has paved the way for an advancing revolution in genetic technology.

In Activity 1 you will examine and apply Mendel's first law of segregation. Then in Activity 2, Mendel's second law of independent assortment will be demonstrated. In Activity 3 you will apply the theories by studying some of the complexities of genetics.

Activity 1: Law of Segregation

WESTFILE INC.

The preceding photo shows how similar foods can be grouped. People often group things. Every department store is organized so that similar products are in the same place. Sizes and colours often determine the order of the racks; then, the manager reorganizes everything for a sale! Where do you find your favourite item?

Once you determine the pattern of organization, everything seems to fall into place and you are comfortable again. This is exactly what will happen in this module, so learning about principles for organizing traits takes place first.

Visions

Read pages 72 to 75 of *Visions 3*. Because understanding the key terms in Table 3.1 on page 75 in your textbook is essential before you can learn about the patterns of inheritance described by Mendel, complete the following Self Test after you review the terms and feel comfortable in evaluating your knowledge.

Self Test

1. Indicate whether each of the following statements is True or False. For each false statement change the bolded term to make the sentence correct.

   _____ a. A **gene** is the part of a chromosome that codes for the expression of a trait.

_____ b. **Alleles** are genes that code for different expressions of the same trait.

_____ c. The genotype for a certain trait will be shown by **three** letters.

_____ d. If an allele is dominant, then a **capital** letter appears in the genotype.

_____ e. If an allele is recessive, then a **capital** letter appears in the genotype.

_____ f. An organism's **phenotype** is the observable traits produced by its genetic code.

_____ g. A homozygous dominant genotype would be written as **Aa**.

_____ h. A heterozygous genotype would be written as **aa**.

gametes – reproductive cells that receive one allele for each gene from the parent

_____ i. If a parental genotype is homozygous, then all **gametes** will receive the **same** allele.

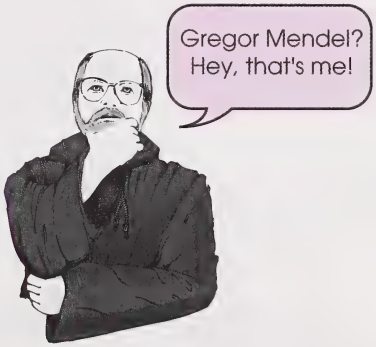
_____ j. If a parental genotype is heterozygous, then **all** gametes will receive the same allele.

Check your answers by turning to the Appendix, Section 1: Activity 1.

Visions

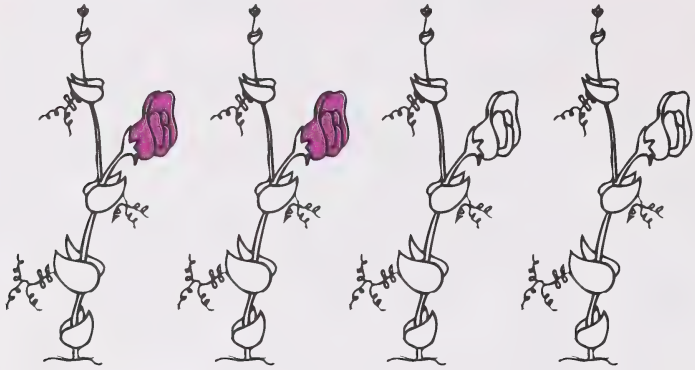
Now you are ready to learn about the organization of genetic traits. Read pages 72 to 74 in your textbook again and answer the following questions.

2. Why is Gregor Mendel considered to be "The Father of Genetics"?



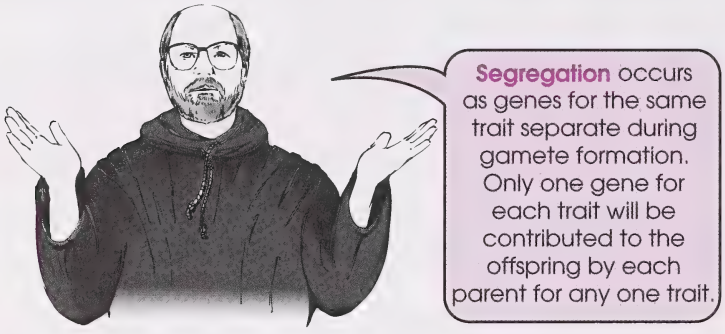
3. What does "true breeding" mean?

4. When true breeding plants for colour (purple and white) are crossed, each parent plant only has one type of allele to donate to each offspring plant. Why are all of these offspring plants called monohybrids?



5. Summarize the law of segregation (Mendel's first law) in your own words.

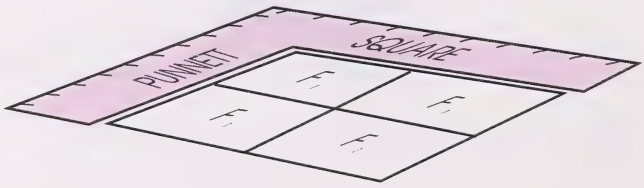
segregation – the separation of the two genes for each specific trait during gamete formation so that each gamete receives only one of these genes


Segregation occurs as genes for the same trait separate during gamete formation. Only one gene for each trait will be contributed to the offspring by each parent for any one trait.

Check your answers by turning to the Appendix, Section 1: Activity 1.

Punnett square – a chart used to predict the genes present in the gametes of parents and the possible genetic combinations in the offspring of the cross

To gain some practical experience in predicting the results of some simple genetic crosses, you will use a **Punnett square**. The Punnett square is commonly used by modern geneticists as a convenience to show the possible genotypes in offspring.



Visions

Read the Practice Problems on pages 75 and 76 in your textbook. Note how the Punnett square is produced.

Example of Monohybrid Cross

Parental genotypes (P_1) { *Aa* and *Aa*

Gametes produced { *A* *a* *A* *a*

P_1 – first parental generation

F_1 – first filial generation (offspring of P_1 cross)

Fertilization of gametes (joining of egg and sperm cells) produce offspring with paired alleles. All of the possible offspring genotypes (F_1) of this sample cross are shown in the following Punnett square.

		Parental gametes *A*	Parental gametes *a*
Parental Gametes	*A* →	*AA*	*Aa*
	a →	*Aa*	*aa*

Offspring summary	
F_1 genotypes	F_1 phenotypes observed
AA	Dominant trait
2 *Aa*	Dominant trait
aa	recessive trait

The presence of a dominant allele (*A*) will produce the dominant trait. Therefore, the phenotypic ratio (dominant:recessive) expected in the offspring will be 3:1.

Visions

6. Complete Problems 1 to 4 from page 76 in your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 1.

If inheritance of characteristics depends on which egg and sperm cells of different gene type meet by chance, are predications made about ratios of possible offspring produced likely to be dependable? Perform Activity 3.1, Understanding Probabilities, which is outlined on pages 76 to 79 in your textbook to gain some understanding of using probabilities in predicting genetic occurrences.

Investigation: Understanding Probabilities

Purpose

Investigate the relationships between chance and inheritance and determine the importance of probabilities in predicting genetic occurrences.

Materials

- coins
- paper and pencil
- ruler

Procedure

- Follow the procedure for Part A as presented on pages 77 to 79 of *Visions 3*. Then complete the Observation and Analysis and Interpretation section for Part A. Once you have completed Part A, do the same for Part B and Part C.

- If you are working alone you might use a class size of twenty students. This means in Part A you would flip your coins twenty times. In step 5 of Part A you would flip your coins five times for each of your twenty students or a total of 100 times. To make things easier, put all three coins in a plastic cup and flip them all at once.

Observations

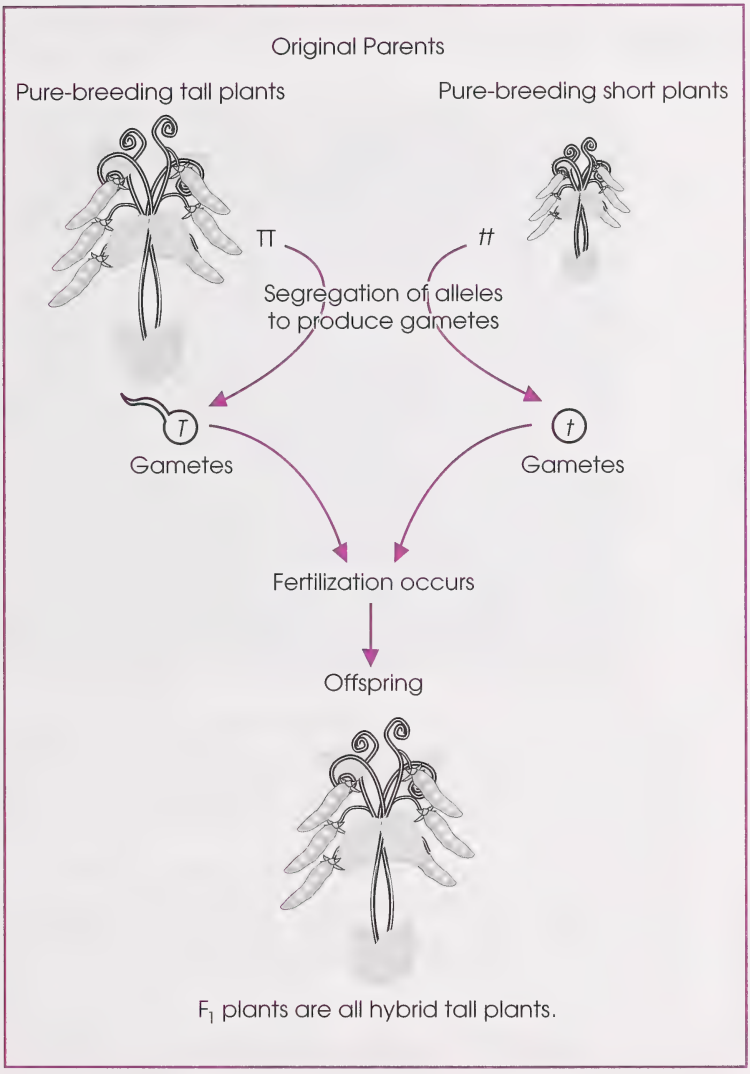
7. Complete each of the tables while you do the investigation.

Analysis and Interpretation

8. Complete all the Analysis and Interpretation questions in Parts A, B, and C on pages 78 and 79 of *Visions 3*.

Check your answers by turning to the Appendix, Section 1: Activity 1.

The law of segregation and a simple cross of homozygous plants for a single trait can be summarized with the following diagram using tall (*TT*) and short (*tt*) pea plants where the allele for tall plants is dominant. One gene for height comes from each parent, but, because the tall allele is dominant, the resulting offspring are all tall.



In this activity you have learned about the law of segregation and the result of uniting gametes to produce offspring. You established that probabilities can be predicted by theoretical means and applied to real genetic situations.

In the next activity you will begin to see the complexities of inheritance when more than one trait is studied.

Activity 2: Law of Independent Assortment

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Do you remember playing sandlot baseball as a child? Teams were chosen and everyone played. The next time, new teams were chosen and the game went on as usual. Each time teams were chosen they were a little different, maybe some players could not play on a particular day. Other times, cousins or visitors were invited to take the field.

Visions

The complexities of team sports, like baseball, compared to individual sports, like tennis, are very much like the complexities of Mendel's second law compared to his first law. To learn about his second law, read pages 80 to 81 in your textbook and answer the following questions.

1. Write Mendel's second law in the following two ways.

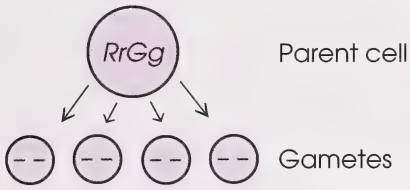
   a. as stated on page 80 of *Visions 3*

   b. in your own words

Mendel's second law can best be illustrated by considering the crossing of hybrid parents (parents whose genes contain different alleles for two different traits). These individuals are said to be **dihybrids**.

dihybrid – heterozygous for two traits

2. Complete the following diagram which shows the possible genotypes of the gametes produced for a pea plant that is a dihybrid (*RrGg*) with round seeds and green pods.



Visions

If you cross two dihybrid parent cells like the preceding one, the resulting combinations are predicted using a Punnett square like the one in Figure 3.5B on page 80 of *Visions 3*.

3. Why does a Punnett square for a dihybrid cross contain sixteen squares?

4. What are the four possible F_2 phenotypes illustrated in Figure 3.5B on page 80 and why are they produced? Remember, only one dominant allele is required for the trait to appear.

F_2 – second filial generation (offspring of F_1 cross)

5. What is the probability (to 2 significant digits) that an F_2 individual from Figure 3.5B will

   a. have round seeds?

   b. have yellow pods?

   c. be homozygous dominant for both traits?

   d. be homozygous recessive for both traits?

   e. be a dihybrid like the F_1 parents?

   f. be homozygous for each trait?

Check your answers by turning to the Appendix, Section 1: Activity 2.

Now that you have established what dihybrid crosses are and how the law of independent assortment works, you are ready to analyse a problem involving dihybrid crosses and illustrating the law of independent assortment.

The following senario allows you to observe inheritance patterns involving dihybrid crosses of guinea pigs.

Jason raised two varieties of purebred guinea pigs for commercial purposes. One variety was black and short-haired, and the other was white and long-haired.

He was interested in maintaining the two pure strains so he kept them in separate pens to prevent interbreeding. Jason's friend Derek wondered what the offspring would look like if the two types were crossed.

One day a black, short-haired male and a white, long-haired female escaped from their pens and spent several hours together. Jason was not certain that mating took place but he didn't want to take a chance so he gave these animals to Derek. Derek finally had his chance to find out what happened when the two types were crossed.

The female guinea pig did turn out to be pregnant. All the offspring she produced from this mating were black and short-haired. Derek mated this pair several times. Each time the offspring were all black and short-haired.

6. Explain the results of this cross.

Derek sold all but two of the young guinea pigs produced by the mating. He kept one male and one female. He then allowed these two guinea pigs to mate and produce offspring over several years. Their offspring were of a variety of types. Some were black and short-haired; some were white and short-haired; some were black and long-haired; some were white and long-haired.

7. Explain the results of this F_1 cross and estimate the ratios of different types of guinea pigs produced.

Derek kept track of the numbers of each type of guinea pig actually produced by his crosses of the two dihybrid pigs. His results for this F_2 generation were as follows:

F_2 Generation Phenotype	Black, short-haired	Black, long-haired	White, short-haired	White, long-haired
Number of Offspring	51	16	19	4

8. Calculate the ratios of the phenotypes actually produced and compare these actual results of the F_1 cross to the phenotype ratio you may have expected.

Are the actual results close to what you may have predicted? Can you explain any discrepancies? Do these results support Mendel's law of segregation and his law of independent assortment?

9. Would it have made any difference to the final results of all the guinea pig breeding if the original parental (P_1) cross had been between a black, short-haired female and a white, long-haired male guinea pig?

Check your answers by turning to the Appendix, Section 1: Activity 2.

Visions

10. To conclude this activity, answer Problems 1 to 3 found on page 81 in your textbook.

Use the following information to answer question 11.

Mendel's laws can be stated as follows:

1. Segregation: An organism's characteristics are controlled by factors (genes) that are normally carried in pairs, but occur singly in the gametes.

2. Independent Assortment: Alleles of genes for different specific traits segregate independently of one another during gamete formation, potentially producing a variety of genotypes in gametes.

Science Skills
- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

11. Using Punnett squares and descriptions, give one example of each of Mendel's laws. Present your answer in paragraphs that are clearly written and logically organized.

Check your answers by turning to the Appendix, Section 1: Activity 2.

The law of independent assortment states that traits are passed on independently of each other. Inheritance of the two traits you analysed was not affected by gender. In the next activity you will learn how gender may affect the results you might obtain when looking at inheritance of different traits.

Activity 3: Principles at Work

Understanding the law of gravity really helps when parachuting! However, other natural laws will govern your safe landing. It is important to know the applications of laws when solving problems.

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Visions

How does a hang-glider overcome the effects of gravity, at least for a while? There has to be a logical explanation. Just like the parachutist or the hang-glider, the geneticist makes use of logical explanations to describe principles at work. Discover an example of this by reading pages 84 and 85 in your textbook. After you finish reading, answer the following questions.

1. The first new concept about inheritance is multiple alleles. Explain this term.

2. The second new concept about inheritance is codominance. Explain this term.

3. A blood type A mother and a blood type B father have three children: one type O, one type AB, and one type A. Explain how this is possible. **Note:** Use a Punnett square.

4. A person with blood type O has a homozygous recessive genotype. Explain.

Check your answers by turning to the Appendix, Section 1: Activity 3.

gender – the sex of an individual, e.g., male or female

chromosomes – long threads of genetic material composed of DNA

The **gender** of an individual human being is inherited in much the same way as other traits. However, in this situation, whole **chromosomes** are involved instead of a few paired genes. These chromosomes are the sex chromosomes (x and y). To learn about this inheritance pattern and some of the traits that are affected by gender, read page 92 in your text very carefully. Study Example 1 of Practice Problems on page 93 in your textbook. Then try the following questions.

5. How many pairs of chromosomes determine the gender of a human being?

6. Give the genotype for a typical male and female human.

7. Use a Punnett square to show why there is a 0.5 probability for a baby to be female or male.

8. Distinguish between sex-linked, sex-limited, and sex-influenced traits.

Visions

9. Answer Problems 1 and 2 on page 93 in your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Some other common sex-linked disorders include hemophilia, brown enamel teeth, congenital night blindness, and optic atrophy. Each of these conditions will be more common in males than in females.

In this section you learned about various traits and how traits are passed on from one generation to the next.

In the next section you will learn about the actual molecules that produce traits and how cells divide so traits can be transmitted.

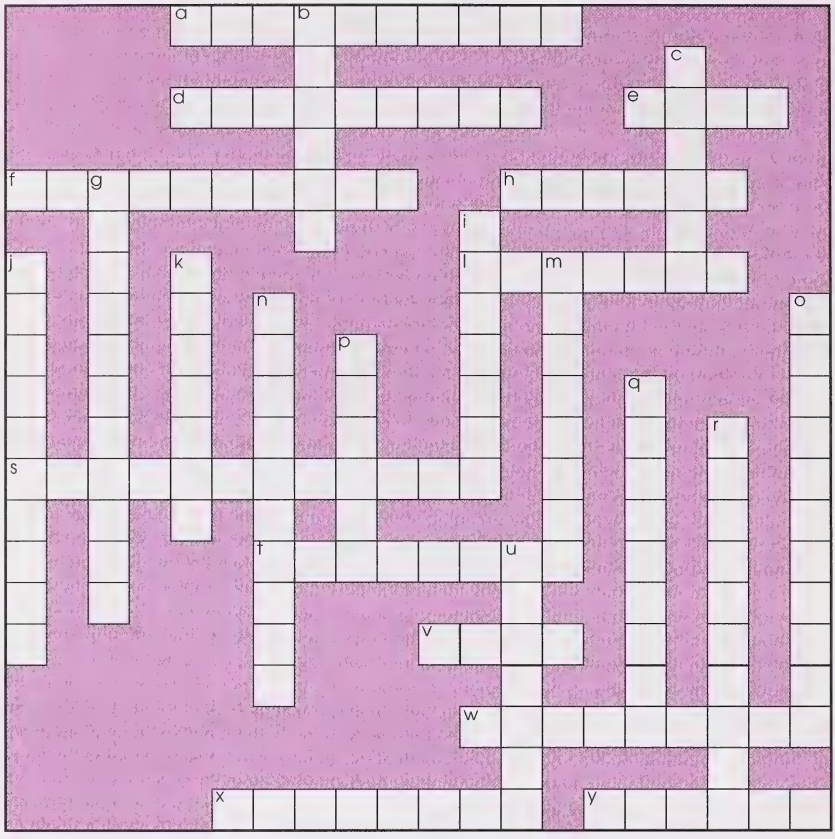
Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

In this section you have learned about Mendel's law of segregation and his law of independent assortment. You have also found out that there are some other unique genetic conditions that exist.

1. Complete the crossword puzzle using terms you have learned in this section and from your textbook.



Across

a. baldness is a sex-_____ disorder
d. the observable expression of genotype
e. XY
f. Mendel's second law of independent _____
h. the father of genetics
l. good milk-producing cows have sex-_____ traits
s. condition where both alleles carried for a specific trait are different
t. the alleles an individual possesses for a trait
v. the basic unit of hereditary information
w. alleles only observed in a homozygous state
x. the allele expressed in heterozygotes
y. XX

Down

b. colourblindness is a sex-_____ disorder
c. the reproductive cell that transmits heredity
g. Mendel's first law of _____
i. alternate forms of the same gene
j. a sex-linked disorder
k. Mendel's genes
m. ABO blood typing is a result of _____ alleles
n. condition where both alleles are the same
o. condition where more than one allele is expressed
p. explained gender determination in *Drosophila*
q. chromosomes that do not determine gender
r. fruit flies
u. the probability square used in genetics

Check your answers by turning to the Appendix, Section 1: Extra Help.

Visions

2. Answer Checkpoint question 2, 3, and 4 found on page 85 in your textbook.

3. A plant homozygous for purple flowers that are found axial on the plant is crossed with a plant that has white flowers that are found terminal on the plant. The F_1 generation is 100% purple, axial flowers. Show the genotypes of the P_1 and F_1 plants and determine the phenotypes and probabilities in the F_2 generation.

Check your answers by turning to the Appendix, Section 1: Extra Help.

4. List all the possible genotypes in the ABO blood typing system. Also identify the resulting phenotypes.

5. A man who is hemophiliac cannot pass this trait to his sons. Explain how this is possible.

6. If a sex-linked allele is dominant, would you expect it to show more commonly in males or females? Explain.

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Visions

1. At the end of Chapter 3 on pages 109 to 111 of your textbook there are chapter questions that help you think, decide, and dream about the concepts presented in this section. Do one or more of the following.

   - Think question 2
   - Think question 3
   - Think question 4

2. Make a poster showing possible transfusions using the ABO system. State which blood type is the universal recipient and which is the universal donor. Explain why.

3. Research a human condition that is thought to be genetic in origin.

Visions

4. If you have access to a laboratory and fruit flies, you may wish to do the following investigation.

Read carefully pages 81 to 83 in *Visions 3*. Perform Activity 3.2, Observing Inheritance Patterns, as outlined.

Investigation: Observing Inheritance Patterns

Science Skills
- [ ] A. Initiating
- [x] B. Collecting
- [x] C. Organizing
- [x] D. Analysing
- [x] E. Synthesizing
- [x] F. Evaluating

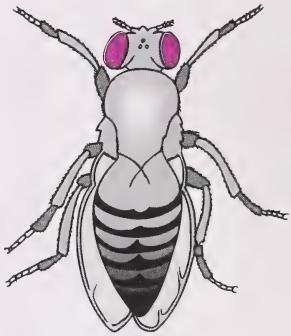
Purpose

Observe the transmission of eye colour and wing structure in three generations of the fruit fly, *Drosophila melanogaster*.

Background Information

The following notation is normally used for these traits.

normal-winged: v^+	red-eyed: s^+
vestigial-winged: v	sepia-eyed: s



Note: Mutant strains show the recessive phenotype. Non-mutant or wild strains show the dominant phenotype for each trait. Normal wings and red eyes are the dominant traits.

Thus a fruit fly with phenotype, normal-winged, sepia-eyed would have a genotype as follows, v^+v^+ss. The genotype of a vestigial-winged, red-eyed fruit fly would be given as vvs^+s^+.

Materials

- listed on page 82 in your textbook

Caution

Procedure

- Weeks 1 to 4 are outlined on pages 82 to 83 in your textbook.
- Careful handling and teacher supervision are required.

Observations

a. Record your results for Weeks 1, 2, 3, and 4 as directed.

Analysis and Interpretation

Visions

b. Complete Textbook questions 1 and 2 in the Analysis and Interpretation section on pages 83 in *Visions 3*.

c. How would your F_2 results differ if the P_1 cross had been a normal-winged, red-eyed female fly with a vestigial-winged, sepia-eyed male fly?

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

Mendelian or classical genetics has unlocked the door to understanding the transmission of traits from parents to offspring. Predictions are possible that help to prepare for and maybe alter the future. Yet there must be more to inheritance than genotypes, phenotypes, and probabilities—and there is.

Assignment Booklet

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 1.

Section

2 Chromosomes and Inheritance

COURTESY OF GANE OLSEN

Have you ever wondered how identical twins are formed? Are they really products of the same genetic information in every cell of their bodies? Is it possible for them to have differences?

These questions generally cause confusion until some of the principles of inheritance and cell division are understood. In Activity 1 of this section you will create a model representing the genetic material that makes up chromosomes. In Activity 2 you will identify the various phases of cell division. Activity 3 will allow you to simulate the transmission of hereditary information.

Activity 1: The Molecules of Heredity

Sometimes a problem to one person is an adventure in creativity to another. It really depends on what is inside! In Section 1 you learned about the transmission of observable traits from one generation to the next. Now you will learn about the "building blocks for life"—the genetic code of **DNA**.

DNA – deoxyribonucleic acid; makes up chromosomes

Read pages 97 and 98 in your textbook and answer the following questions.

1. What great discovery was made from experimentation by Oswald Avery?

2. How did Watson and Crick contribute to the advances in molecular genetics?

3. The basic unit of DNA is a nucleotide. It is composed of a _____ sugar, a _____, and one of four nitrogenous _____, which bond together to form the **double helix** shown in Figure 3.12, on page 98 in your text.

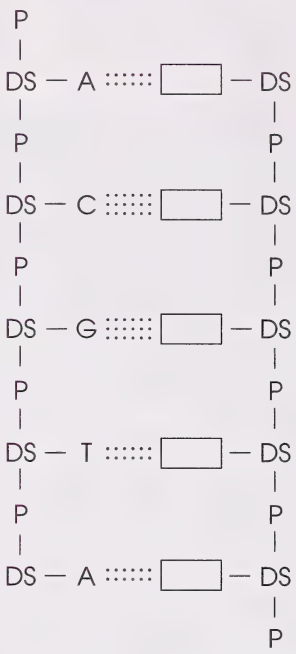
double helix – two spiralled strands of DNA held together by hydrogen bonds

The symbols for various parts of the nucleotide are as follows.

deoxyribose sugar — DS
phosphate ion — P
Adenine — A
Cytosine — C
Guanine — G
Thymine — T

4. The genetic code is the sequence of bases in DNA. Using Figure 3.12, indicate the specific bases pairings found in DNA.

5. For the following sequence of bases in the DNA molecule, complete the complementary base pairings by filling in each box with the correct symbol for the missing nitrogenous base.



Note: The hydrogen bonds between the bases are shown by the dots. This is what holds the double helix together.

Check your answers by turning to the Appendix, Section 2: Activity 1.

If you have access to the video, *Protein Synthesis: The Molecule of Heredity*, TVOntario, ACCESS Network, you may wish to view this video for more information on the base sequences in the DNA molecule. This video may be obtained through your local school or library or may be purchased from the Learning Resources Distributing Centre.

The great mystery of heredity is solved in part by understanding how DNA is copied and decoded in the construction, regulation, and duplication of cells.

To learn more about these processes, read pages 99 and 100 in your text and answer the following questions.

6. Why is DNA replication such an important cellular process?

7. How can the DNA make exact copies of itself?

8. The genetic code is really a set of instructions for building proteins which carry out many essential cell processes. In your own words describe DNA transcription and **RNA** translation. Write your answer in a well-organized paragraph.

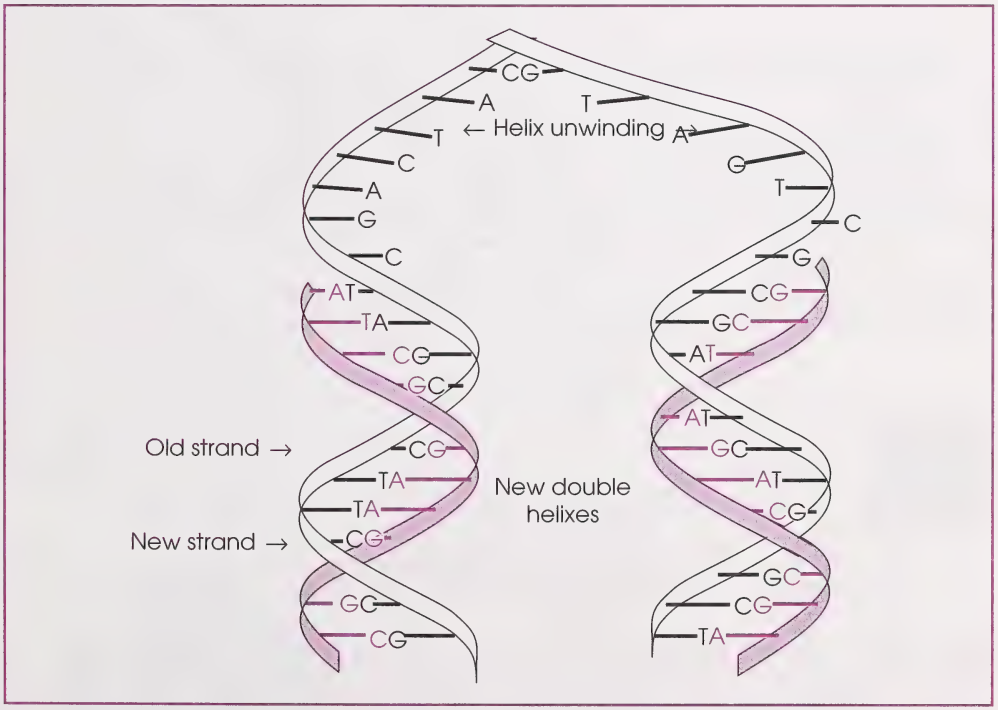
RNA – ribonucleic acid, a molecular strand formed during DNA transcription which passes on DNA information about protein synthesis

Check your answers by turning to the Appendix, Section 2: Activity 1.

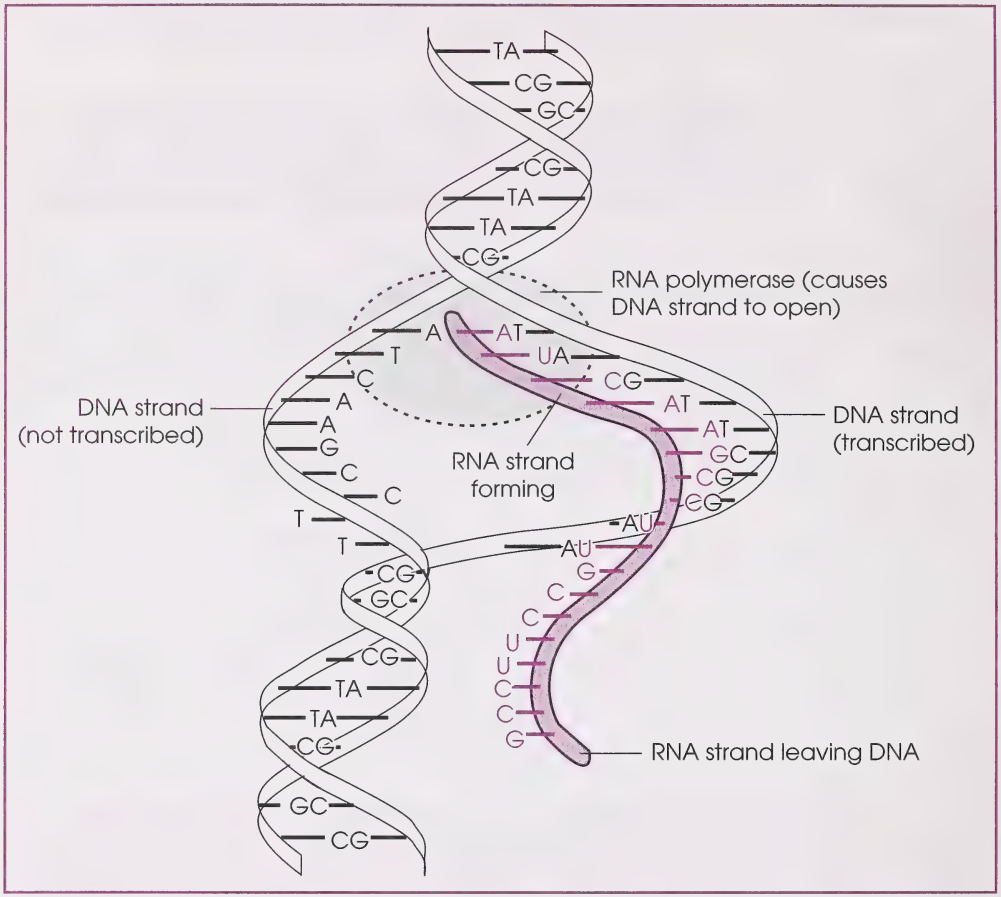
As you can see from the preceding reading and questions, there are two copying processes involving DNA. The first process is DNA replication or copying the DNA to form **sister chromatids** for each chromosome before any type of cell division. The DNA strand separates and each strand combines with new nucleotides to form two identical double helixes. The second process is DNA transcription in which the DNA strand opens itself up and a messenger RNA strand forms based on one part of the DNA strand. The RNA strand then leaves the DNA and makes its way to the cytoplasm to form protein and the double helix of the DNA reforms.

sister chromatids – the pair of identical DNA strnads comprising a chromosome that has replicated

DNA Replication



DNA Transcription


RNA polymerase (causes DNA strand to open)
DNA strand (not transcribed)
DNA strand (transcribed)
RNA strand forming
RNA strand leaving DNA

The video and investigation that follow will help you to understand these processes.

View the ACCESS video, *Protein Synthesis* — "DNA Replication: The Repeating Formula." This video is available from the Learning Resources Distributing Centre or you may be able to obtain it through your local school or library.

Familiarize yourself with the following questions first. As you view the video, answer the questions. Stop the tape whenever necessary.

purine – double-ringed base

pyrimidine – single-ringed base

9. What constitutes a full complement of DNA?

10. What two **purines** and two **pyrimidines** are found in DNA? What is the pyrimidine that replaces thymine in RNA?

11. How are identical copies of DNA produced in cells before cell division?

Check your answers by turning to the Appendix, Section 2: Activity 1.

Science Skills
- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

Investigation: Simulating DNA Replication

Purpose

Show how the double helix of DNA can be copied exactly.

Materials

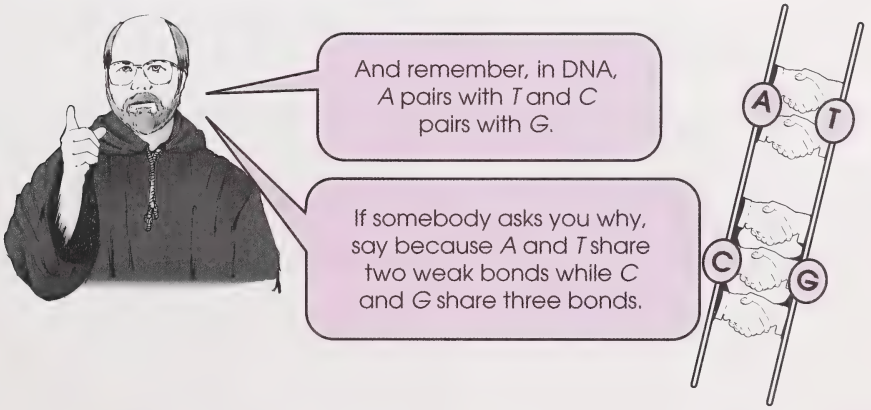
- scissors
- coloured pencils
- transparent tape
- pages of symbols for DNA (in Appendix)
- blank sheet of paper

Procedure

- Carefully cut out the individual molecules from the page of symbols for DNA found at the end of the Appendix.
- Using the transparent tape, bond a deoxyribose sugar, a phosphate, and a base.

nucleotide – a sugar, a phosphate, and a base bonded together

- Colour the base of each **nucleotide** with different coloured pencils (adenine—blue, thymine—green, guanine—red, cytosine—yellow).
- Create a single strand of DNA by choosing six nucleotides and arranging them in a straight line on the blank sheet of paper. **Note:** Each nucleotide will bond between a sugar and a phosphate. This forms the backbone of DNA.
- Create the complementary strand of the DNA helix by matching the bases of new nucleotides with the original strand.


And remember, in DNA, A pairs with T and C pairs with G.
If somebody asks you why, say because A and T share two weak bonds while C and G share three bonds.
A
T
C
G

- To replicate this molecule of DNA and create two DNA molecules from the original DNA molecule, separate the strands and tape them to the paper. **Note:** These strands should be far enough apart to allow you to insert new nucleotides for each strand.

- Now match the remaining free nucleotides to the strands you have taped down.

- Complete the investigation by taping down the new strands of DNA to the paper. You will have created two DNA molecules, identical to each other and to the original DNA molecule model.

Observations

12. The double helix of DNA is like a ladder. What parts of each nucleotide represent the "rungs" or steps and what parts represent the side posts?

codons – groups of three bases in the DNA that specify for particular amino acids

13. How many **codons** are in your single strand of DNA?

14. Describe the colour sequence for your double strand of DNA and your two new DNA molecules.

Analysis and Interpretation

15. What determines the base sequence for each new molecule of DNA you created?

16. Identify the problem that would be created if adenine joined with guanine or cytosine.

17. How would a strand of mRNA compare to your new strands of DNA?

Check your answers by turning to the Appendix, Section 2: Activity 1.

To check your understanding of DNA transcription to mRNA and the translation of mRNA to amino acids, do the following questions.

18. A section of DNA is to be transcribed to produce the complementary strand of mRNA. Give the complementary mRNA strand for the DNA strand provided.

DNA TAC | TTC | GCA | ATA | CCG | AGC |

mRNA

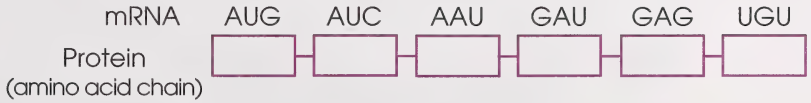
Use the following chart to give the sequence of amino acids that will be linked together when the mRNA is translated. Write the name of the amino acid in the box.

mRNA Codons and Corresponding Amino Acids

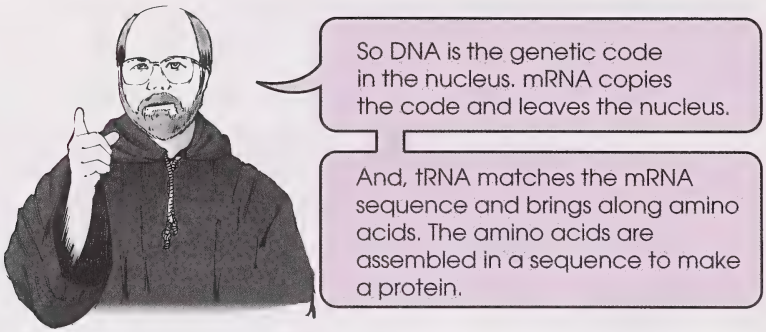
First Base	Second Base U	Second Base C	Second Base A	Second Base G	Third Base
U	phenylalanine	serine	tryosine	cysteine	U
	phenylalanine	serine	tryosine	cysteine	C
	leucine	serine	*chain terminates*	*chain terminates*	A
	leucine	serine	*chain terminates*	tryptophan	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	threonine	asparagine	serine	U
	isoleucine	threonine	asparagine	serine	C
	isoleucine	threonine	lysine	arginine	A
	methionine (starts message)	threonine	lysine	arginine	G
G	valine	alanine	aspartic acid	glycine	U
	valine	alanine	aspartic acid	glycine	C
	valine	alanine	glutamic acid	glycine	A
	valine	alanine	glutamic acid	glycine	G

To use this chart, locate the point where first, second, and third base columns interse For example, the codon UUU will code for phenylalanine since this is the amino acid named where the three "U" base columns and rows all intersect.

19. Make a linked set of boxes like the following and write the name of the amino acid in each box.



Check your answers by turning to the Appendix, Section 2: Activity 1.


So DNA is the genetic code in the nucleus. mRNA copies the code and leaves the nucleus.
And, tRNA matches the mRNA sequence and brings along amino acids. The amino acids are assembled in a sequence to make a protein.

For more information on messenger RNA and transfer RNA, you may wish to watch the video programs *RNA Synthesis: The Genetics, Messenger* and *Transfer RNA: The Genetic Messenger*, TVOntario, ACCESS Network. These videos may be obtained through your local school or library or purchased from the Learning Resources Distributing Centre.

Genes are simply portions of the sequence of nitrogenous bases in the DNA that code for specific traits. Since the DNA forms a chromosome, the activity of chromosomes in cell division can help to explain the transmission of heredity. This is the subject of the next activity.

Activity 2: Cell Cycling

Have you ever tried to repeat a complex action? Did it work out exactly the same? Most of the time an action that is practised again and again is performed the same. The major events are identical, even though the details may be slightly different.

Visions

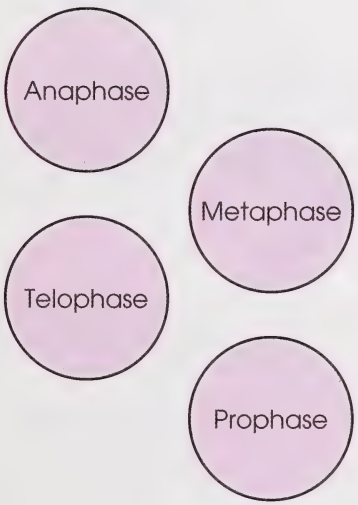
The life cycle of every body cell except the cells producing gametes is basically the same. Major events occur the same way in all types of cells. To learn about basic cell division, read pages 85 and 86 as well as the first two paragraphs on page 87 in your text. Then answer the following questions.

1. How did the work of Sutton and Boveri contribute to the chromosome theory of inheritance?

2. Briefly describe the four parts of the cell's life cycle.

chronological – in order of time (earliest to latest)

3. Organize the following phases and descriptions of mitosis in **chronological** order and match each description to the appropriate phase name.



a. Chromosomes align at the equator of the spindle.

b. New nuclei form at poles of the spindle and cytokinesis ends.

c. Chromosomes become visible and the spindle forms.

d. Chromatids separate at equator and move toward poles.

4. Cytokinesis is the division of the cytoplasm between the two new cells.

   a. During which phase does cytokinesis occur?

   b. What happens to the cell membrane at this stage?

   c. What is the interphase?

Check your answers by turning to the Appendix, Section 2: Activity 2.

The following investigation will help you identify the various phases in mitosis.

PATHWAYS

If you have access to laboratory facilities and chemical stains, do Part A. If you do not have access to a laboratory, then do Part B.

Investigation: Chromosomes in Mitosis

Science Skills
- [ ] A. Initiating
- [x] B. Collecting
- [x] C. Organizing
- [x] D. Analysing
- [x] E. Synthesizing
- [ ] F. Evaluating

Part A

Purpose

Identify the phases of mitosis in rapidly dividing onion root tip cells.

Background Information

The live onion root tip is a good source of cells that are rapidly dividing. Interrupting the process and staining the chromosomes will allow you to actually see what happens. The length of time for each phase will be obvious by the number of cells found in each phase. The longer the phase, the more cells you will find in that phase.

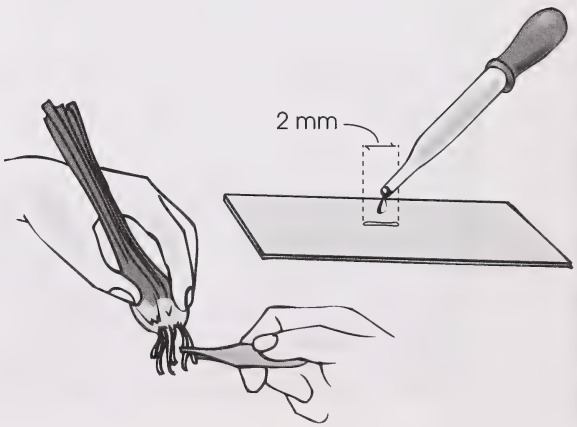
Materials

- fresh onion with roots
- paper towels
- acetocarmine stain
- 1 mol/L HCl
- slide and cover slip
- safety goggles
- scalpel or razor blade
- bunsen burner and matches
- microscope
- forceps
- eyedropper

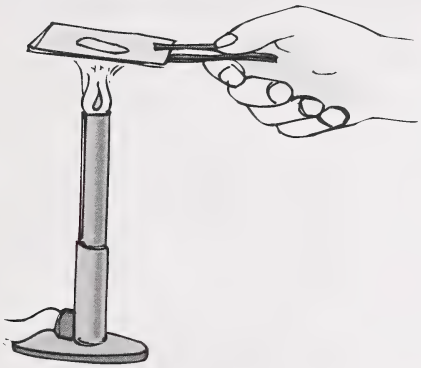
Procedure

Caution

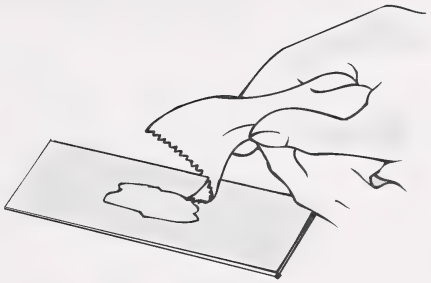
Step 1: Cut off a piece of onion root tip about 2 mm long and place it on a slide. Add three drops of HCl. Use safety goggles when working with acids.



Step 2: Over the next three minutes pass the slide over the flame of the bunsen burner to heat the acid. Use the forceps to hold the slide. **Note:** Do not let the acid boil.

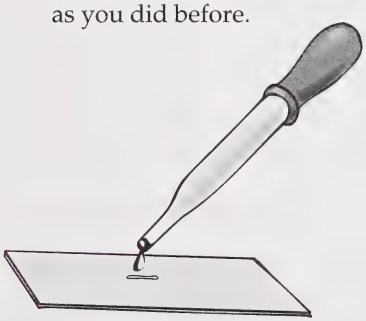


Step 3: Absorb the excess acid with a paper towel.



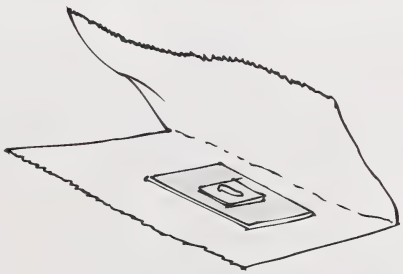
mince – to cut into fine pieces

Step 4: Add one drop of acetocarmine stain and let stand for one minute. Then warm the slide as you did before.

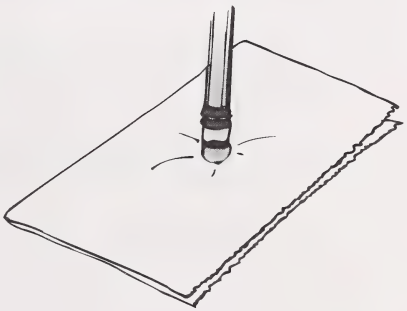


Step 5: Add a fresh drop of the stain and **mince** the onion root tip thoroughly with the scalpel.

Step 6: Place the cover slip on the stained root tip and put the slide between the folded halves of a paper towel.



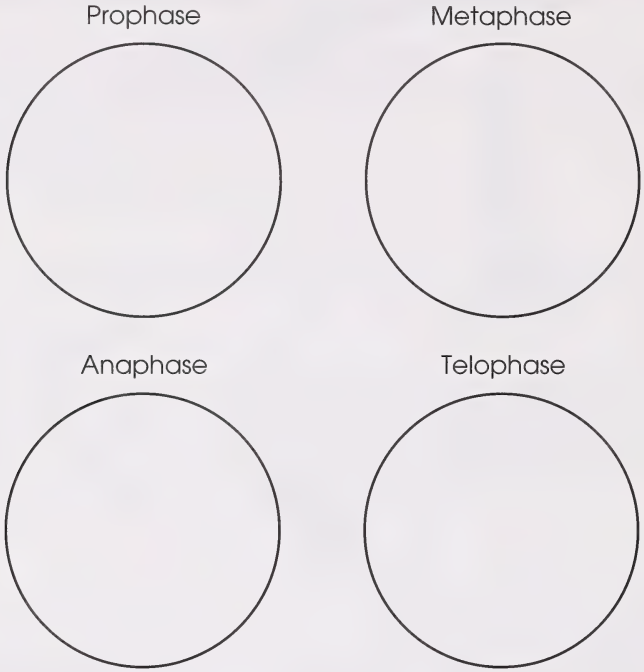
Step 7: Squash the root tip by carefully pressing down on the slide with your thumb or the eraser end of a pencil.



Step 8: Clean any excess stain off the slide and observe under low and medium power.

Observations

5. Identify each phase of mitosis and draw the nucleus of the cell showing the stained chromosomes. Do your drawings in circles like the following.



6. Make and complete a chart like the following one by observing 60 cells.

Total Cells	Interphase	Prophase	Metaphase	Anaphase	Telophase
60					

Analysis and Interpretation

7. Why would an onion root tip be a good place to look for dividing cells?

8. If mitosis of onion root tip cells takes one hour, how many minutes would each phase last? What would the relative length of the entire life cycle be? Use the following formula to answer the first part of this question.

$$\text{time for a phase} = \frac{\text{number of cells in that phase}}{\text{total number of cells in sample}} \times \text{total time for mitosis}$$

9. How would a cell without a full set of chromosomes function?

Check your answers by turning to the Appendix, Section 2: Activity 2.

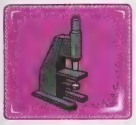
Science Skills
- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part B

Purpose

Observe photomicrographs of mitosis in onion cells.

Materials



- microslide viewer
- microslide set 55, Plant Mitosis
- unlined paper and pencil

Procedure

- Carefully observe Slides 1 to 8 after reading the descriptions.

Observations

10. On a separate piece of unlined paper, draw diagrams of Slides 3, 5, and 7. Identify the condition of the chromosomes in each slide.

Analysis and Interpretation

11. Explain why some of the cells in each slide are not undergoing mitosis and show no activity in their nuclei.

Check your answers by turning to the Appendix, Section 2: Activity 2.

The essence of one cell growing and dividing to produce two new cells has been presented. It is this basic process that underlies the principles of heredity. However, this type of cell division does not produce variety.

In the last activity in this section you will learn about another type of cell division that allows multiplication with variation.

Activity 3: Divide and Multiply

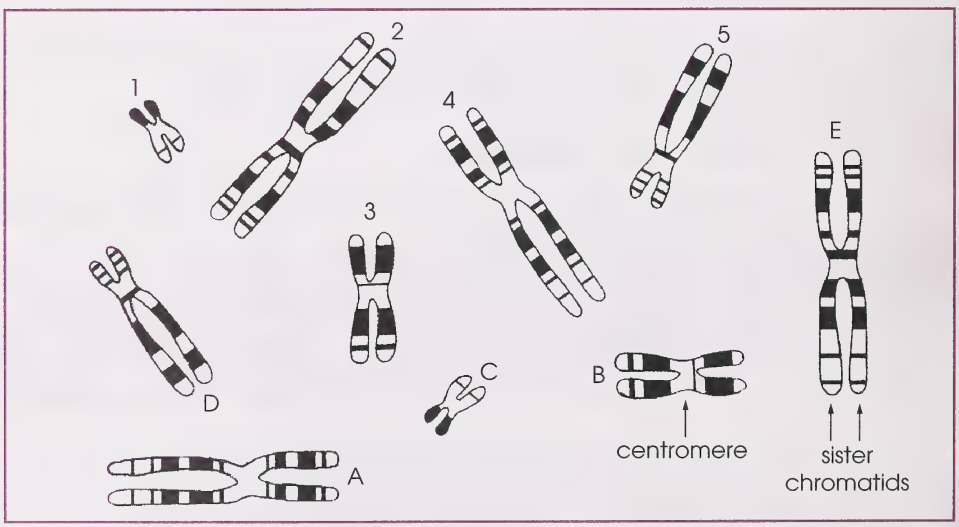
Do you like to put puzzles together? Have you found that many puzzles have certain-shaped pieces and there is a simple pattern you can follow to complete an intricate landscape? Discovering these sequences can make puzzle solving enjoyable and possible!

Over many years cell biologists have put together the puzzle of cell division. The activity of chromosomes transmits hereditary information from one generation to the next. You have already learned that mitosis will allow reproduction without variation. Each new cell is an exact copy of the parent cell as a result of DNA replication. Multicellular species use mitosis to grow and replace worn-out cells. However, in order for a species to survive, reproductive cells are rarely genetically identical. This provides the variation that is essential to the survival of a species.

Visions

Read pages 87 to 89 in your textbook to learn about a different type of cell division called meiosis. When you finish reading, answer the following questions.

1. The following chromosomes have replicated and are made of sister chromatids. There are five pairs of homologous chromosomes shown here. Organize the homologous chromosome pairs by matching a number with a letter. Explain your answers.



2. Explain the result of crossing over during prophase of meiosis I.

3. How is meiosis I different from mitosis?

4. Gametes are formed by meiosis II. Explain what happens during meiosis II.

The condition of the gametes formed by meiosis II is known as haploid (n). Biologists use the term *haploid* with regard to cells that have only half the normal number of chromosomes or one set of homologs (n). Diploid (2n) refers to cells having two sets of chromosomes which can be arranged in homologuous pairs.

5. a. How are meiosis and meitosis similar?

   b. How are meiosis and meitosis different?

6. a. How is gamete formation in human males different from that of human females?

   b. Describe the results of **fertilization**.

fertilization – the process of a sperm uniting with an egg

7. Differentiate between meiosis I and meiosis II.

Check your answers by turning to the Appendix, Section 2: Activity 3.

Investigation: Meiosis in Ascaris

Science Skills
- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Purpose

Observe photomicrographs of meiosis in a parasitic worm, the ascaris.

Materials

- microslide viewer
- microslide set 92, Meiosis
- unlined paper and pencil

Procedure

- Observe Slides 1 to 6 carefully after reading the description. You will need to refer back to these slides as you answer the questions in the Analysis and Interpretation section.

Observations

8. On a separate piece of unlined paper, draw diagrams of Slides 3 and 6. Identify the following on your diagram:

   - tetrad 1 and tetrad 2 (T_1, T_2)
   - sperm (S)
   - second polar body (PB_2)
   - egg (E)

Analysis and Interpretation

9. Why are the parts labelled T_1 and T_2 in Slides 1 and 2 called tetrads?

10. What do you notice about the positions of the chromosomes in Slide 3?

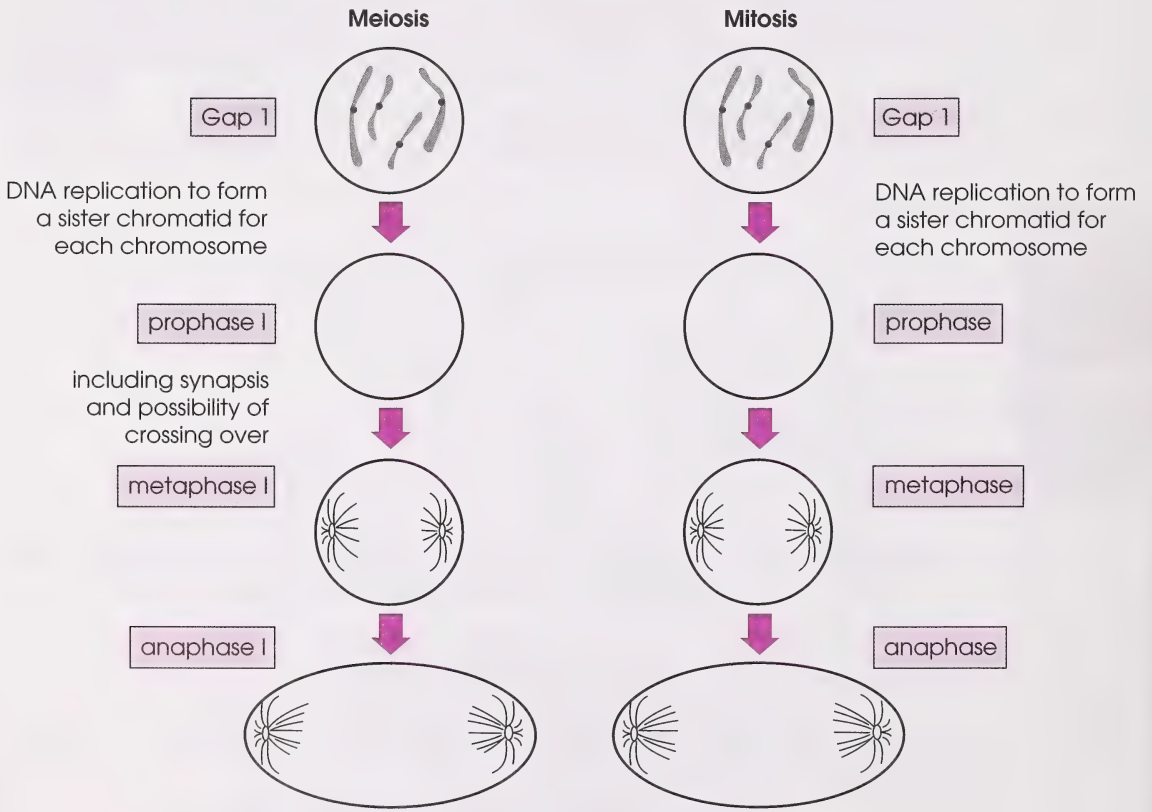
11. Which slides would most likely show stages of meiosis I? Which slide shows the start of meiosis II?

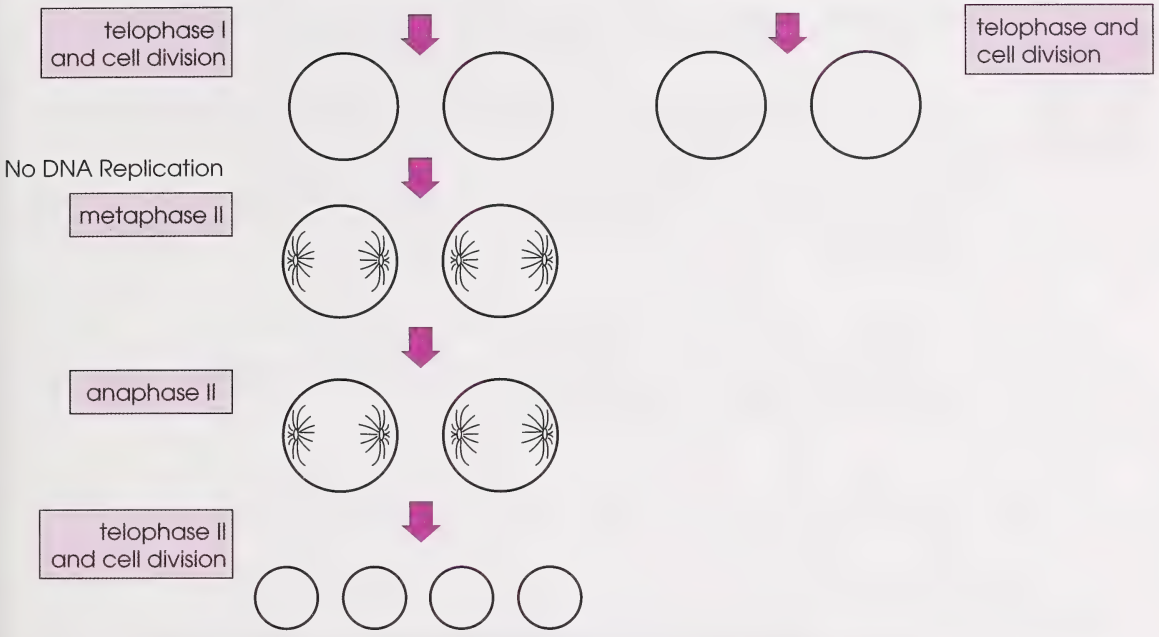
12. Where do the chromosomes that separate and move out of the cell go?

13. What happens to the polar bodies?

The following diagrams compare chromosome activity in meiosis and mitosis.

14. Redraw and complete the diagram by drawing the changes to chromosomes in each blank cell or each cell that contains no chromosomes. Identify four differences between these processes of meiosis and mitosis.





Check your answers by turning to the Appendix, Section 2: Activity 3.

For more information on meiosis, you may wish to watch the video *Organic Evolution, Meiotic Mix*, ACCESS Network. This video may be obtained through your school or local library or purchased from the Learning Resources Distributing Centre.

The puzzle of cell division is now complete. Mitosis allows the cells of an organism to divide and produce exact copies. Meiosis allows special cells of an organism to become gametes that may be genetically different. Fertilization allows organisms to produce offspring with combinations of traits from parental gametes. The resulting genotypes and phenotypes can be astronomically variable.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

In this section you have learned about chromosomes and how traits are inherited as a result of cell division.

Visions

Use Figure 3.12 on page 98, Figure 3.13 on page 99, and Figures 3.14 and 3.15 on page 100 in your textbook to answer the following questions.

1. Explain why each of the four nitrogenous bases in DNA will only bond with one complementary base in the formation of the double helix.

2. If the base pairs that are split in the DNA molecule shown in Figure 3.13 represent the genetic code for a single gene, then how many base pairs and codons are in this gene?

3. Describe the process of DNA transcription.

4. Using the information in Figure 3.15, identify the mRNA codons that are specific for the following amino acids in the protein.

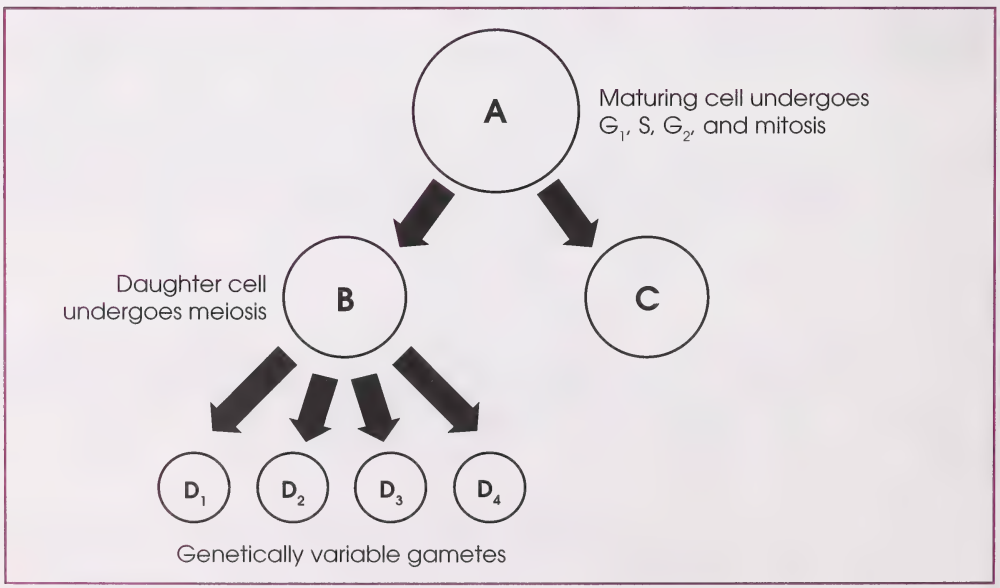
   a. lysine (lys)

   b. phenylalanine (phe)

   c. glycine (gly)

Check your answers by turning to the Appendix, Section 2: Extra Help.

The following diagram shows a schematic of a maturing cell.



Use the preceding diagram and the following word list to complete questions 5 to 8. You may use each term more than once.

anaphase	homologous	telophase
chromatids	metaphase	transcription
crossing over	prophase	gametes
cytokinesis	synapsis	zygote

5. Cell A begins to grow as a result of DNA _____, which produces mRNA molecules for each of the active genes. The ribosomes will be the site of RNA _____ and protein synthesis, so active genes can produce traits in maturing cells.
6. By the time mitosis begins, Cell A will have replicated its DNA and produced sister _____ for each of the _____ chromosomes present. During _____ the spindle begins to form and the chromatids are visible. The centromeres attach to spindle fibres and align all of the chromatid pairs at the equator during _____. Separation of the chromatid pairs during _____ allows new Cells B and C to receive the same genetic information as Cell A had. Nuclear division or mitosis is completed during _____, and _____ will divide Cell A into Cells B and C.
7. If Cell B were then to grow to maturity, replicate its chromosome and undergo meiosis, then during meiosis I the chromosomes of Cell B will align in tetrads or pairs of homologs. This is called _____ and may allow chromatids to exchange genetic information in a process called _____. Homologous chromosomes will separate during _____ I of meiosis. In meiosis II, the chromatids of each chromosome will separate to produce mature _____. The union of male and female gametes produces a _____ and ensures genetic variation in the offspring of organisms.

8. How would the formation of gametes differ if Cell B was produced in a female instead of a male?

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

Do one or more of the following to apply the concepts you have learned in this section.

1. Predict the effect of a drug that permanently binds the complementary nitrogenous bases of DNA together.

2. DNA fingerprinting has been used to identify criminals. Read the article that follows. Investigate this technique further and write a well-organized report. Suggest other applications of this technology.

Crime Lab[1]

DNA fingerprinting has received much attention in the O.J. Simpson murder trial, but it is only one of many tools available to scientific investigators.

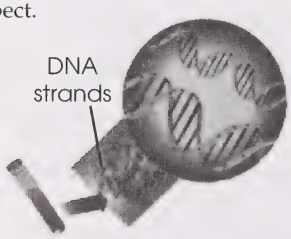
DNA fingerprinting

Every cell of the human body contains DNA, the chemical that carries the genetic code. DNA molecules are chains of about 12 billion chemical "bases." The four kinds are represented as A, T, C and G.

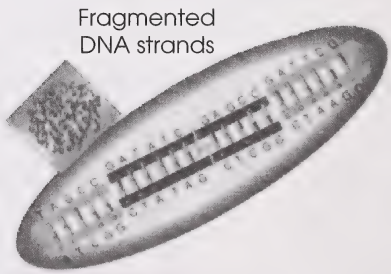
Any two people (except for identical twins) have different sequences of bases at about 3 million sites along the DNA strand.

Here's how a laboratory tests for matching DNA.

1. DNA is extracted from blood, hair, semen or other tissue found at crime scene and from a sample from the suspect.

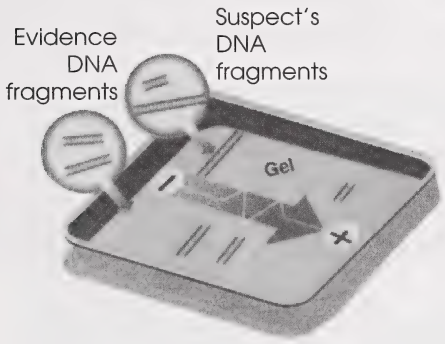


2. Chemicals called **restriction enzymes** cut the DNA strand every place they find a sequence of bases, such as "CCGAT." In different people, those fragments vary slightly in length and weight.

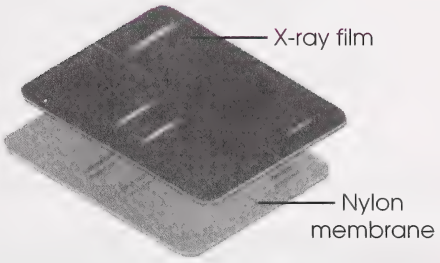


[1] Reprinted by permission: Tribune Media Services

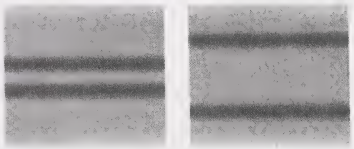
3. A drop of sample is put on a tray of gel. An electric current pulls the fragments along the gel. Heavier fragments move a short distance; lighter fragments go farther.



4. Pattern of tracks is stuck to a nylon membrane and treated with radioactive chemicals that bind to the DNA fragments.



5. The membrane is pressed for several days against X-ray film, which records the radioactivity. In this example, there is no match between the evidence DNA and that of the suspect.



3. Why are organ transplants more successful between identical twins than between other individuals?

4. Tissue cloning produces offspring that are identical to their parents. Predict some of the potential problems that might arise if all plant reproduction were controlled by tissue cloning.

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

Discovering the sequence to the puzzle of cell replication makes it possible to enjoy the finished landscape of heredity. The precision of this sequence is amazing. Phase after phase, chromosomes are copied and transferred to new cells. However, sometimes mistakes are encountered that lead to some devastating abnormalities and intriguing remedies!

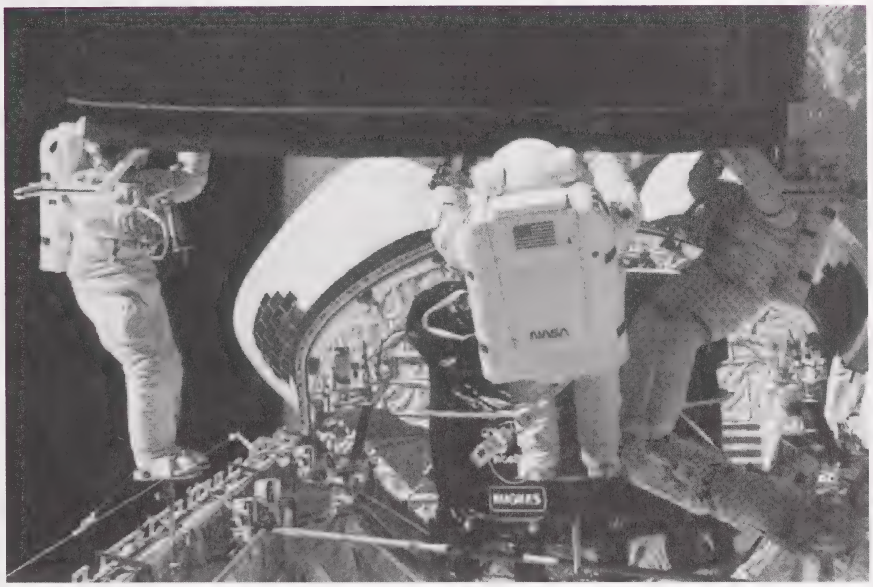
Assignment Booklet

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 2.

Section

3 Genetic Applications



NASA

Have you ever wondered what it would be like to be an astronaut and travel in space? Would it really be like the movies or is technology not that advanced yet? Tremendous strides have been taken since the first manned voyage into space. However, there are giant leaps yet to come that will allow greater exploration of space.

This is just how it is in genetic exploration. Instead of reaching out, genetic researchers are reaching in—into the complexities of the cell machinery that produces hereditary traits. These discoveries lead to decision making that may directly influence your future!

In this section you will learn about various applications of the principles of genetics. First, in Activity 1 you will observe traits in a human population and apply mathematical equations to establish the frequency of these traits. Then in Activity 2, you will theorize about some common chromosome problems and how these can be detected. Activity 3 will allow you to hypothesize what the future holds for possibly correcting genetic abnormalities.

Activity 1: Population Genetics

You have probably heard that no two individuals are exactly the same. The biological significance of this fact was not understood until the patterns of heredity were discovered. Mendel's laws and the cell cycle of growth, replication, and division have paved the way for understanding the transmission of traits within populations.

Visions

To learn about population genetics, read from the middle of page 89 to the end of page 91 in your textbook and answer the following questions.

1. What is a gene pool?

2. Describe the Hardy-Weinberg principle in your own words.

3. In a population, will the dominant phenotype of a characteristic be observed more frequently than the recessive form? Explain your answer based on what you learned in Section 1.

4. Are there traits for which patterns of inheritance cannot be explained on the basis of dominant and recessive alleles? Explain.

Check your answers by turning to the Appendix, Section 3: Activity 1.

To help you understand the mathematical methods used by Hardy and Weinberg, you may want to review Mendel's first law presented in Section 1, Activity 1. You will see in the following presentation how closely aligned these discoveries really are.

COMPARISON OF HARDY-WEINBERG PRINCIPLE WITH MENDEL'S FIRST LAW

Equation for Hardy-Weinberg Principle	Mendel's First Law
If p is the frequency of the dominant allele for a trait in a population and q is the frequency of the recessive allele for the same trait in the population, then $p+q=1$.	In a monohybrid cross ($Aa \times Aa$), A represents the dominant allele and a represents the recessive allele. In each parent these alleles segregate or separate at gamete formation.

Squaring both sides of the equation gives $p^2 + 2pq + q^2 = 1$, where

- p^2 is the frequency of the homozygous dominant allele genotype
- $2pq$ is the frequency of the heterozygous genotype (This group is carriers of the recessive allele which do not exhibit the trait.)
- q^2 is the frequency of the homozygous recessive allele genotype

When predicting possible genotype ratios of a monohybrid cross

- *AA* represents the homozygous dominant genotype,
- 2*Aa* represents the heterozygous genotype, and
- *aa* represents the homozygous recessive genotype.

The following two examples show how the Hardy-Weinberg equation works in theory.

Example 1

If a gene pool contains 200 alleles, and 180 are dominant (*A*) and 20 are recessive (*a*),

then $p = \frac{180}{200}$ or 0.9

and $q = \frac{20}{200}$ or 0.1.

Example 2—Theory

If $p = 0.9$ and $q = 0.1$ and the whole population $= p^2 + 2pq + q^2$,

then $p^2 = 0.81$ or 81% of the population is *AA*

$2pq = 0.18$ or 18% of the population is *Aa*

$q^2 = 0.01$ or 1% of the population is *aa*.

Note: Multiply by 100 to change a frequency to a percentage of the population.

The dominant expression of the trait will be observed in 99% (*AA* and *Aa*) of the population. The recessive phenotype is seen in only 1% of the population.

The following example shows you the results of a real study in human populations.

Example 3—Practical

cystic fibrosis – a disease that involves the production of abnormal amounts of mucus in lungs and pancreas

If 1 in 2000 live-born children are affected by the recessive disease of **cystic fibrosis**, then

$q^2 = \frac{1}{2000}$ or $0.0005 = 0.05\%$ (aa) (diseased)

and $q = \sqrt{0.0005}$ or 0.022

and $p = 1 - q$ or 0.978

Therefore, $p^2 = 0.96$ or 96.0% (AA) (normal)

and $2pq = 0.0395$ or 3.95% (Aa) (normal but who carry a recessive gene for the disease). This describes the population genetics for the disease of cystic fibrosis.

Using the information given about the Hardy-Weinberg principle, answer the following questions that apply this knowledge to a sample population.

5. The frequency for black coat colour (the recessive allele) in leopards is 0.17. Determine the frequency for the dominant allele of spotted coat colour.

6. Based on your calculations for coat colour in leopards, what percentage of the population of leopards in an area will be black?

7. How many leopards in a population of 1000 would be considered carriers for the recessive allele because they are heterozygous?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Visions

To apply what you have learned about population genetics, perform Activity 3.3, Observing Genes in Populations, as found on pages 89 to 91 in your textbook.

Investigation: Observing Single Trait Characteristics

Science Skills
- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

Purpose

Survey a group of people to observe the frequency of alleles for certain human traits.

Materials

- paper and pencil
- 10 subjects to survey (More subjects may be surveyed if you are in a classroom.)

Procedure

Visions

- Complete Steps 1 to 5 as found on pages 90 and 91 in your textbook. If you are in a classroom, use the entire class as subjects. If you are working at home, try to find at least ten friends and relatives to use as subjects. Sample results for the PTC tasting test are included as the chemical; phenylthiourea in the PTC paper is toxic and leaves an extremely bitter taste for those who can taste it.

Observations

8. Make and complete a table, similar to the one shown in Figure 3.9 on page 91, to record the data you collect for the seven traits and the Hardy-Weinberg calculations. Sample results and required calculations for PTC tasting are included in the Appendix.

Analysis and Interpretation

9. Complete Textbook questions 1 and 2 found on page 91.

10. How does the mathematical model for the Hardy-Weinberg principle assist you in your study of human population genetics?

Check your answers by turning to the Appendix, Section 3: Activity 1.

In this activity you have learned about gene pools and frequencies of alleles in populations. New technology is helping researchers to identify the causes of genetic abnormalities. In the next activity you will learn about some common, yet unusual genetic conditions that exist.

Activity 2: Nondisjunction

What's wrong with the following sentence?

> THESE ALS ARE BARKING.

If you are the owner of two dogs named Al, then maybe there is nothing wrong with this sentence. However, if you look a little closer, then you will realize that the letters have not been divided into the right words.

> THE SEALS ARE BARKING.

This sentence makes much more sense.

Sometimes errors occur in the transmission of genetic information because chromosomes, like letters, "stick" together instead of segregating correctly. To learn about this unusual condition, read pages 94 to 96 in your textbook. Then answer the following questions.

1. At what stages of meiosis do chromosomes segregate?

2. Evaluate the significance of nondisjunction.

trisomy – three chromosomes present instead of two

3. What causes **trisomy** 21 or Down Syndrome?

4. Describe Dr. Renée Martin's findings in her investigations of chromosomal abnormalities in gametes.

Check your answers by turning to the Appendix, Section 3: Activity 2.

karyotype – a magnified photograph of chromatid pairs at metaphase

Dr. Martin has suggested new methods for detecting chromosome abnormalities that may help geneticists determine how to prevent these conditions. An example of this technology is **karyotyping**. To simulate what is done in a laboratory and learn about the usefulness of this technique, perform the following investigation.

Investigation: Human Karyotyping

Purpose

Determine chromosome abnormalities by using a karyotype chart.

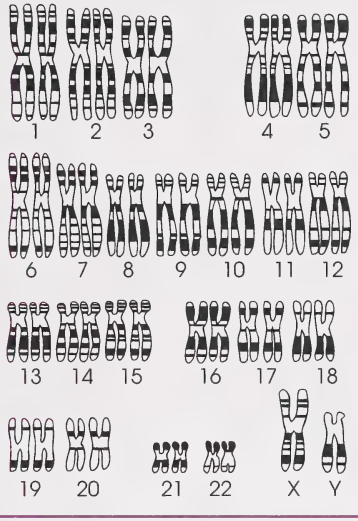
Materials

- Individual A Karyotype (found at the end of the Appendix)
- human karyotype chart
- scissors
- blank paper and tape or glue-stick

Procedure

- Study the following normal human karyotype chart to identify the size, shape, and bonding of each chromosome pair.

A human karyotype chart using chromosomes with simulated banding



Note: This chart is produced by taking a photograph of the chromosomes of a cell after DNA replication has occurred. Sister chromatids are joined by centromeres.

- Using the sample karyotype of Individual A, found at the end of the Appendix, cut out each of the chromosomes and pair them.
- Match the paired chromosomes to the previous human karyotype chart and arrange them on the blank sheet of paper. Tape or paste them in place.
- Use the following chart to identify any genetic disorder in Individual A's karyotype.

Chromosome abnormality	Syndrome (condition)	Effects on individual (variable)
X0	Turner	• sterile female • underdeveloped female characteristics • short stature • sometimes below normal intelligence
XXY	Klinefelter	• sterile male • abnormal male characteristics • abnormally long arms and legs • below normal intelligence

Trisomy #21	Down	• low mental ability • short arms and legs • internal defects • distinct facial features
Trisomy #18	Edward	• severe abnormalities • life expectancy about 10 weeks
Trisomy #13	Patau	• severe defects including small, non-functioning eyes • survive only a few weeks after birth
Defective #5 (part of chromosome missing)	*Cri-du-chat*	• severe defects, both physical and mental • when crying, sound similar to cat's meow

Observations

5. In what ways does chromosome pair 4 differ from chromosome pair 19 in the human karyotype chart?

6. What is the gender of the individual in the human karyotype chart?

7. How many chromosomes does Individual A have?

8. What is the gender of Individual A?

9. Based on the karyotyping you have done for Individual A, identify the abnormal condition.

Analysis and Interpretation

10. Would the diagnosis of Klinefelter syndrome in a single cell mean that every cell of that individual would have 47 chromosomes? Explain your answer.

11. How would it be possible for a Down syndrome father and a Down syndrome mother to produce a normal child?

Check your answers by turning to the Appendix, Section 3: Activity 2.

In this activity you have identified some of the abnormalities that result from improper transfer of genetic information during meiosis. The field of genetics is constantly changing. New technologies such as human karyotyping and DNA probes can provide geneticists with much information about chromosome abnormalities. As new technologies open the mysteries of inheritance, the future could see the elimination of genetic abnormalities. In the next activity you will learn about other types of errors and how manipulation of genetic material can be useful to humans.

Activity 3: Mutations and Genetic Engineering

"An ounce of prevention is worth more than a pound of cure." This saying reveals much about mutation research. Being able to prevent a genetic disorder from being expressed may certainly be worth more than all the drugs or therapy used to treat the condition.

Visions

In this last activity you will learn about mutations of DNA and how technology allows researchers to manipulate genes. First, read about mutations on pages 101 and 102 in your textbook and answer the following questions.

1. What is a mutation? Explain a possible cause.

2. Explain how a point mutation alters the results of DNA transcription, RNA translation, and subsequent protein synthesis. Use the point mutation that causes sickle cell anemia in your explanation. Refer to Figure 3.16 on page 102 of *Visions 3*.

3. Why is the development of cancer not hereditary (passed from parents to offspring)?

4. How is phenylketonuria an example of a hereditary disorder?

Check your answers by turning to the Appendix, Section 3: Activity 3.

Visions

Being able to identify the complete normal genetic code for a human being makes it possible to diagnose and treat mutations. Read about the Human Genome Project on page 103 in your textbook and answer the following questions.

5. If the human genetic code is found in 46 chromosomes and 100 000 genes, then why are there approximately 3 billion base pairs?

6. Why is it fitting that James Watson head the project?

Check your answers by turning to the Appendix, Section 3: Activity 3.

Second, the recombinant DNA technology is exploding. Selecting individual genes and adding them to the genetic code of another organism still sound like science fiction.

Visions

To learn about Recombinant DNA Technology, read pages 102 to 105 in your textbook and answer the following questions.

7. What is the essential role played by restriction endonucleases?

8. How is a foreign gene introduced into the bacteria?

9. What is the advantage of using recombinant DNA technology over artificial treatments?

10. Describe four applications of this technology.

11. Do Think question 10 found on page 110 of *Visions 3*.

12. Do Decide question 2 found on pages 110 and 111 of *Visions 3*.

Check your answers by turning to the Appendix, Section 3: Activity 3.

For hundreds of years humans have been able to manipulate the genes of plants and animals for agricultural purposes. Scientists are just learning how to manipulate genetic material. The power to influence the genetic makeup of plant and animal species, including humans, requires a knowledgeable and scientifically literate population. These individuals must understand the biological concepts and see the broad societal ramifications.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

In this section you have learned about population genetics and the frequencies of alleles.

1. If the frequency for the recessive allele, which causes sickle cell anemia, is 0.09, then how many humans in a population of 100 000 are expected to show this genetic disorder?

   Hint:
   $q = 0.09$
   q^2 = frequency of homozygous recessive genotype
   $q^2 \times 100\,000$ = number of sickle cell anemics

2. How many individuals would be considered carriers for sickle cell anemia?

   Hint:
   $p = 1 - q$
   $2pq$ = frequency of heterozygous genotype
   $2pq \times 100\,000$ = number of carriers

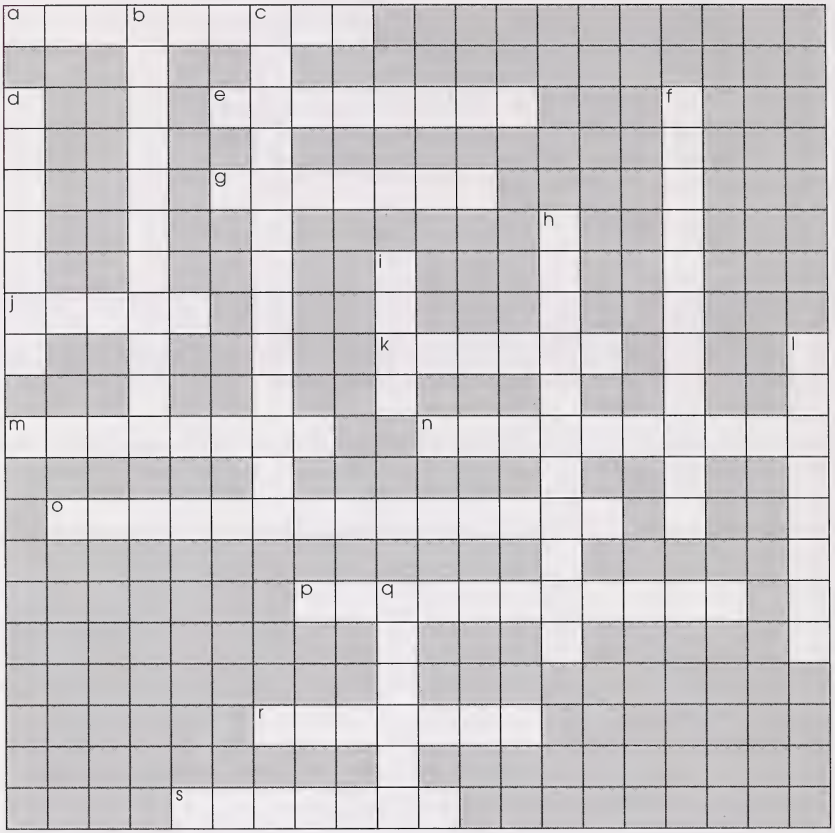
3. How many individuals cannot transmit this genetic disorder to their offspring?

   Hint:
   $p = 0.91$
   p^2 = frequency of homozygous dominant genotype
   $p^2 \times 100\,000$ = number of non-carriers

Check your answers by turning to the Appendix, Section 3: Extra Help.

You have also learned about genetic disorders caused by nondisjunction and about recombinant DNA technology used to correct mutations.

4. Complete the following crossword puzzle.



Across

a. During meiosis, chromosome pairs _____ twice.
e. a gene that contributes to the development of cancer
g. Edward's syndrome is produced by _____ 18.
j. A single base pair change in DNA is a _____ mutation.
k. the original head of the Human Genome Project
m. organism used in genetic engineering
n. defective blood-clotting mutation
o. abnormal segregation of chromosome pairs
p. Selective transfer of genes is genetic _____.
r. cell division that produces gametes
s. chemical that alters the sequence of bases in DNA

Down

b. _____ DNA contains a new gene.
c. chromosome deviations
d. Gene _____ treatments of AIDS are being tested.
f. enzymes necessary for cutting DNA
h. Humans have 46 _____ in each body cell nucleus.
i. the syndrome resulting from an extra chromosome 21
l. small circular pieces of DNA in bacteria
q. the DNA in one complete set of human chromosomes

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

Do one or more of the following.

1. The Hardy-Weinberg mathematic model for three alleles is

$$p + q + r = 1$$

$$p^2 + 2pq + 2pr + 2qr + q^2 + r^2 = 1 \text{ (squaring both sides)}$$

The frequency of the ABO blood group alleles in a population is
$I^A = 0.26$, $I^B = 0.06$, $i = 0.68$

Calculate the frequency (to 2 significant digits) of the blood groups A, B, AB, and O in this human population.

2. Do Checkpoint question 4 found on page 97 of your text.

3. Do Think question 8 found on page 110 of your text.

4. Do Projects question 2 found on page 111 of your text.

Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

Just like the untimely explosion of the space shuttle *Columbia*, human genetic disorders can rob life from the hope of a better tomorrow. Technology has rebuilt the shuttle, and wisdom should prevent another disaster. Genetic engineering is making diagnosis and correction of genetic disorders possible. Will wisdom prevail when applying genetic knowledge? This question is a very hard one to answer, but now you have some of the knowledge necessary to try.

Assignment Booklet

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 3.

MODULE SUMMARY

In this module you have learned that the patterns of heredity are predictable and follow basic principles of cell division. Mitosis maintains the continuity of genetic codes, while meiosis assures genetic variation that allows fertilization to produce new combinations of DNA. Errors in the expression of hereditary information occur and current technology is striving to identify and correct these mistakes. The challenge of the future lies in using genetic knowledge with wisdom.

Appendix

Glossary

Suggested Answers

DNA Symbols

Individual A Karyotype

Glossary

chromosomes: long threads of genetic material composed of DNA

chronological: in order of time (earliest to latest)

codons: groups of three bases in the DNA that specify for particular amino acids

cystic fibrosis: a disease that involves the production of abnormal amounts of mucus in lungs and pancreas

dihybrid: heterozygous for two traits

DNA: deoxyribonucleic acid; makes up chromosomes

double helix: two spiralled strands of DNA held together by hydrogen bonds

F_1: first filial generation (offspring of P_1 cross)

F_2: second filial generation (offspring of F_1 cross)

fertilization: the process of a sperm uniting with an egg

gametes: reproductive cells that receive one gene for each specific trait from the parent

gender: the sex of an individual, e.g., male or female

karyotype: a magnified photograph of chromatid pairs at metaphase

mince: to cut into fine pieces

nucleotide: a sugar, a phosphate, and a base bonded together

P_1: first parental generation

population genetics: the study of the frequencies of alleles in a gene pool

Punnett square: a chart used to predict the gametes in parents and the possible genetic combinations in the offspring

purine: double-ringed base

pyrimidine: single-ringed base

RNA: ribonucleic acid, a molecular strand formed during DNA transcription which passes on the DNA information about protein synthesis

segregation: the separation of the two genes for a trait during gamete formation so that each gamete receives only one gene for each specific trait

sister chromatids: the pair of identical DNA strands comprising a chromosome that replicated

trisomy: three chromosomes present instead of two

Note: The crossword puzzles found in the Extra Help of Sections 1 and 3 provide the definitions for many important terms in this module.

Suggested Answers

Section 1: Activity 1

1. The additional information after the answer to each question is provided to give you a greater understanding of the terms. This information was not required in your answer.

   a. **True** Chromosomes contain all of the genetic code and a gene is simply a portion of the whole chromosome.

b. **True** The gene may be for flower colour. Alternate forms of the gene for this trait are alleles. The alleles for flower colour, for example, may be red (*R*) and white (*r*). The capitalization of letters indicates which allele is dominant (red—*R*) and which is recessive (white—*r*).

c. **False, two** Since the genes or factors are paired, the genotype will be shown by using two letters to represent each allele (e.g., *AA* or *Aa* or *aa*).

d. **True** Using the convention established by Mendel, the dominant allele is written with a capital letter (e.g., *A*).

e. **False, lower case** Recessive alleles may be masked by dominant alleles in the expression of a trait (e.g., *Aa*).

f. **True** If the genotype is *RR* or *Rr*, then the flower colour will be red, which is the dominant colour. Only the *rr* genotype will produce a white flower. Thus, the genotype will determine which phenotype or trait is observed.

g. **False, *AA*** Homozygous indicates that the two alleles are the same; dominant is indicated by the use of a capital letter.

h. **False, *Aa*** Heterozygous indicates that the two alleles are different.

i. **True** If the parental genotype is *AA* or *aa*, all the gametes will receive only the allele the parent possesses.

j. **False, half of the** When the parental genotype is *Aa*, then half the gametes will receive the dominant *A* allele and the other half will receive the recessive *a* allele.

2. Mendel was first to analyse the inheritance patterns of selected traits in garden peas by applying statistical methods to his data. His explanations have been verified by modern technology. Mendel is called "The Father of Genetics" in honour of his work.

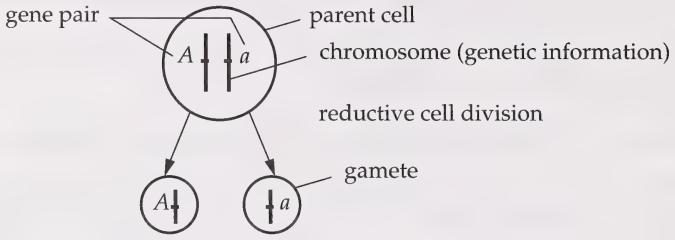
3. A true-breeding organism is homozygous for the trait. Its genotype is either *AA* (dominant) or *aa* (recessive).

4. True-breeding plants are homozygous. Therefore, the parental genotypes will be *PP* (purple) and *pp* (white). Each parent has only one type of allele to donate to the gametes, so all the offspring will be *Pp*. Since the alleles the offspring receive are different, the plants are known as monohybrids.

5. Your summary should include each of the following key points:

   - Parental genotypes show the alleles contained for two genes for each trait.
   - During gamete formation or reductive cell division, the two genes for a specific trait will be separated into different gamete cells.
   - Fertilization of an egg cell by a sperm cell will restore the pair of genes for each trait. Depending upon which sperm cell fertilizes which egg cell, a number of different combinations of alleles may be possible in the offspring.

This illustration may help you visualize the process of segregation.



6. **Textbook question 1:**
   P_1 Genotypes ($Rr \times Rr$)
   F_1 Genotypes using the Punnett square are as follows.

	R	*r*
R	*RR*	*Rr*
r	*Rr*	*rr*

F_1 Phenotypes
- round seeds (1 *RR* and 2 *Rr*)
- wrinkled seeds (1 *rr*)

There will be $\frac{3}{4}$ of the offspring that have round seeds.

Textbook question 2: Only 1 of the 4 possible genotypes is RR, so $\frac{1}{4}$ will be homozygous round.

Textbook question 3:
P_1 Genotypes ($Oo \times oo$)
F_1 Genotypes using the Punnett square are as follows.

	o	*o*
O	*Oo*	*Oo*
o	*oo*	*oo*

Phenotypes
- tongue-rollers (2 *Oo*)
- non-tongue-rollers (2 *oo*)

There will be a $\frac{2}{4}$ or 50% chance you will be a tongue-roller.

Textbook question 4:
P_1 Genotypes ($Oo \times Oo$)
F_1 Genotypes using the Punnett square are as follows.

	O	*o*
O	*OO*	*Oo*
o	*Oo*	*oo*

Phenotypes
- tongue-rollers (1 *OO* and 2 *Oo*)
- non-tongue-rollers (1 *oo*)

There is a $\frac{1}{4}$ or 25% chance that you could not roll your tongue.

7. The following are sample results based on a class size of 55 students. Your class size would probably have been different but the rounded ratios should be close to the same.

Part A

	3 Girls	2 Girls, 1 Boy	1 Girl, 2 Boys	3 Boys
Trial 1	7	20	22	6
Ratios	$\frac{7}{7} = 1.00$	$\frac{20}{7} = 2.86$	$\frac{22}{7} = 3.14$	$\frac{6}{7} = 0.86$
Rounded	1	3	3	1
Trial 2	34	104	101	36
Ratios	$\frac{34}{34} = 1.00$	$\frac{104}{34} = 3.06$	$\frac{101}{34} = 2.97$	$\frac{36}{34} = 1.06$
Rounded	1	3	3	1

Part B

	3 Girls			2 Girls, 1 Boy			1 Girl, 2 Boys			3 Boys		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
	G	G	G	B	G	G	G	B	B	B	B	B
				G	B	G	B	G	B			
				G	G	B	B	B	G			
Ways	1			3			3			1		
Ratio	$\frac{1}{8}$			$\frac{3}{8}$			$\frac{3}{8}$			$\frac{1}{8}$		

Part C

	2 Girls		1 Girl, 1 Boy		2 Boys	
	1st	2nd	1st	2nd	1st	2nd
	G	G	G	B	B	B
			B	G		
Ways	1		2		1	
Ratio	$\frac{1}{4}$		$\frac{2}{4}$		$\frac{1}{4}$	

8. Your answers should be similar to the following.

Part A

Textbook question 1: A pattern should emerge where the results for the 3 girls and 3 boys are equal numbers, while the other two columns are equal, but three times the first and last columns.

Textbook question 2: Yes, the values in row 5 are closer to the values in row 6 than the values in row 2 are to the values in row 3. The more trials you attempt, the more likely the results will conform to theory.

Textbook question 3: The prediction would be based on how many possible combinations there are and the probability ratios of occurrence.

Part B

Textbook question 1: The numbers from each column in rows 3 and 6 should be the same as the numerator of the fraction in the last row in the table for Part B.

Textbook question 2: There is **1** chance in **8** that in a family of three children there would be three girls. There are **3** chances in **8** that in a family of three children there would be one girl and two boys.

Textbook question 3: The chance of a particular combination of children occurring is the ratio of that sequence over the total possible combinations.

Textbook question 4: Probability of 3 girls $= \frac{1}{8} = 0.125$

Probability of 2 girls, 1 boy $= \frac{3}{8} = 0.375$

Probability of 1 girl, 2 boys $= \frac{3}{8} = 0.375$

Probability of 3 boys $= \frac{1}{8} = 0.125$

Part C

Textbook question 1: Answers will vary, but should verify the theory if enough trials are completed. The predication should be 1:2:1.

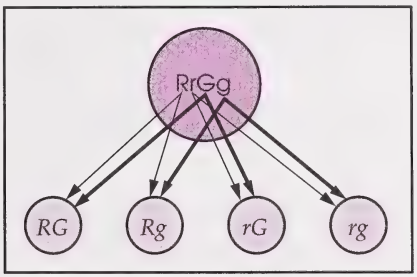
Textbook question 2: The larger the sample size, the more accurately your data will match the theory. The experiment should be designed such that large sample sizes can be obtained. For example, in a prediction such as this a computer simulation would work well.

Section 1: Activity 2

1. a. Mendel's second law states that during gamete formation, the alleles from two or more traits segregate independently of one another.

   b. Whether a gamete carries dominant or recessive alleles for one trait has no effect on the alleles carried for a second trait.

2. Half the gametes receive the allele *R* and half receive *r*. Half the gametes receive *G* and half receive *g*. **Note:** Random assortment of alleles from the parent cell to the gametes allows an equal probability for *R* and *G*, *R* and *g*, *r* and *G*, and *r* and *g* to combine in gametes. This is a good example of the law of independent assortment (Mendel's second law) in action.



3. Since each parent in a dihybrid cross can produce four genetically different gametes, there will be 16 (4×4) possible combinations of gametes to produce offspring.

4. The F_2 phenotypes are the result of the genotypes that result from gametes uniting. The following Punnett square shows the possible genotypes of the crosses and is coded to illustrate the possible phenotypes.

	RG	*Rg*	*rG*	*rg*
RG	*RRGG*	*RRGg*	*RrGG*	*RrGg*
Rg	*RRGg*	*RRgg*	*RrGg*	*Rrgg*
rG	*RrGG*	*RrGg*	*rrGG*	*rrGg*
rg	*RrGg*	*Rrgg*	*rrGg*	*rrgg*

Offspring Phenotypes

→ round seeds and green pods $\left(\frac{9}{16}\right)$

→ round seeds and yellow pods $\left(\frac{3}{16}\right)$

→ wrinkled seeds and green pods $\left(\frac{3}{16}\right)$

→ wrinkled seeds and yellow pods $\left(\frac{1}{16}\right)$

Whenever at least one dominant allele is contained for a trait, the variation of the trait coded for by this dominant allele will appear in the phenotype of the offspring. Recessive alleles only assert their effect when the dominant allele is absent from the genotype. Only one dominant allele is necessary to produce the dominant phenotype thus resulting in the combinations shown. This answer will help you understand the answers to each part of question 5.

5. a. Out of 16 possible offspring, nine offspring will have round seeds and green pods and three will have round seeds and yellow pods.

$$\text{Probability of having round seeds} = \frac{12}{16}$$
$$= 0.75$$

Note: All of the clear boxes and grey boxes in the preceding answer have a dominant allele for round seeds.

b. Out of 16 possible offspring, three offspring will have round seeds and yellow pods and one offspring will have wrinkled seeds and yellow pods.

$$\text{Probability of having yellow pods} = \frac{4}{16}$$
$$= 0.25$$

Note: All of the light-coloured boxes and the dark-coloured box have two recessive alleles for yellow pods.

c. Only one square in the Punnett square is homozygous dominant for both traits. It is found in the upper left-hand corner of the square.

$$\text{Probability of being homozygous dominant for both traits} = \frac{1}{16}$$
$$= 0.063$$

d. Only one square in the Punnett square is homozygous recessive for both traits. It is found in the lower right-hand corner of the square.

$$\text{Probability of being homozygous recessive for both traits} = \frac{1}{16}$$
$$= 0.063$$

e. There are four squares that are dihybrid. They form a diagonal line of clear boxes from upper right to lower left in the Punnett square.

$$\text{Probability of being a dihybrid like the } F_1 \text{ parents} = \frac{4}{16}$$
$$= 0.25$$

f. There are four squares that are homozygous for each trait. They form a diagonal line from upper left to lower right in the Punnett square.

$$\text{Probability of being homozygous for each trait} = \frac{4}{16}$$
$$= 0.25$$

6. The offspring were all black and short-haired because each of the purebred parent guinea pigs was able to produce only one type of gamete, and when the sperm from the male fertilized egg cells from the female, only one genotype in the offspring was possible. This genotype produced offspring of the black, short-haired phenotype, because alleles producing black colour and short hair were dominant.

P_1: Male ♂

Phenotype → black, short-haired

Genotype → BBSS

All gametes produced are (BS)

Female ♀

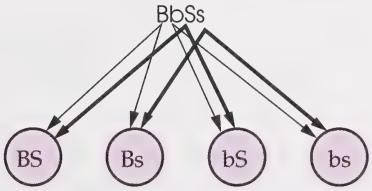
Phenotype → white, long-haired

Genotype → bbss

All gametes produced are (bs)

P_1 Cross (BS) x (bs) ⟶ BbSs genotype in all offspring. All offspring will be black and short-haired.

7. If two dihybrid guinea pigs were now crossed, each parent could produce four different types of gametes, because the alleles for colour and hair length carried by these dihybrid pigs could assort in four different ways.



A Punnett square shows the crossing of two guinea pigs of the same dihybrid genotype.

Punnett Square for the Dihybrid Cross

Possible Female Gametes

Possible Male Gametes	*BS*	*Bs*	*bS*	*bs*
BS	*BBSS*	*BBSs*	*BbSS*	*BbSs*
Bs	*BBSs*	*BBss*	*BbSs*	*Bbss*
bS	*BbSS*	*BbSs*	*bbSS*	*bbSs*
bs	*BbSs*	*Bbss*	*bbSs*	*bbss*

Derek should have noticed four different types of guinea pigs resulting from the dihybrid cross, illustrated as follows.

→ black, short-haired $\frac{9}{16}$ or 0.56 probability

→ black, long-haired $\frac{3}{16}$ or 0.19 probability

→ white, short-haired $\frac{3}{16}$ or 0.19 probability

→ white, long-haired $\frac{1}{16}$ or 0.06 probability

8. Ratios of phenotypes actually produced by Derek's dihybrid crosses are as follows.

black, short-haired— $\frac{51}{90}$ or 0.57 probability

black, long-haired— $\frac{16}{90}$ or 0.18 probability

white, short-haired— $\frac{19}{90}$ or 0.21 probability

white, long-haired— $\frac{4}{90}$ or 0.04 probability

Comparison of Predicted Results to Actual Results of F_1 Cross		
F_2 Generation Phenotype	**Predicted Results**	**Actual Results**
black, short-haired	0.56	0.57
black, long-haired	0.19	0.18
white, short-haired	0.19	0.21
white, long-haired	0.06	0.04

Actual results in offspring of the dihybrid cross are quite close to predicted results. If the sample of offspring was larger, the results may be even closer. Both the law of segregation and law of independent assortment are supported by these results. Mathematically this can be shown as follows.

- One Trait: law of segregation
  From the law of segregation you previously found that the phenotypic ratio for dominant to recessive traits is 3:1.
  From the probabilites of the actual results you can calculate the phenotypic ratio of dominant to recessive alleles for both colour and hair length.

	Colour		Hair Length	
	Black	**White**	**Short-haired**	**Long-haired**
Sum of Probabilities	0.57 + 0.18 = 0.75	0.21 + 0.04 = 0.25	0.57 + 0.21 = 0.78	0.18 + 0.04 = 0.22
Phenotypic Ratio	0.75 to 0.25 or 3:1		0.78 to 0.22 or 3:1	

The phenotypic ratio for colour is 0.75 to 0.25 or 3:1 and 0.78 to 0.22 or approximately 3:1 for hair length. These results support the law of segregation.

- Two Traits: law of independent assortment
  From the law of independent assortment you previously found that the phenotypic ratio for a dihybrid cross is 9:3:3:1 and that the predicted probabilities are 0.56, 0.19, 0.19, and 0.06 for the resulting combinations. From the actual probabilities for this problem as given in the chart in the answer to question 8, the probabilities were 0.57, 0.18, 0.21, and 0.04. These probabilities are close to the probabilities predicted by the law of independent assortment; hence, the results support this law.

9. The F_2 result would be the same. The sex of the parent makes no difference in the transfer of these traits.

10. **Textbook question 1:**
Genotype → *TTii*
Phenotype → dominant for stem height = tall (*TT*)
recessive for pod shape = pinched (*ii*)

The phenotype of this pea plant is tall and pinched pod.

Genotype → *ttII*
Phenotype → recessive for stem height = short (*tt*), dominant for pod shape = inflated pod (II)

The phenotype of this pea plant is short and inflated pod.

Textbook question 2:
P_1: *TTii* × *ttII*
gametes: *Ti* *tI*
F_1: 100% *TtIi* (Dihybrids)

Textbook question 3: Results of a dihybrid cross

F_2: tall, inflated $\frac{9}{16} = 0.56$

tall, pinched $\frac{3}{16} = 0.19$

short, inflated $\frac{3}{16} = 0.19$

short, pinched $\frac{1}{16} = 0.06$

homozygous for both $\frac{4}{16} = 0.25$

Note: Refer back to the answers for questions 4 and 5 for explanations.

11. An example of a trait that illustrates Mendel's first law is pod colour of peas. Pea pod colour can be green or yellow with green being dominant. The pod colour would be represented as *G* for green and *g* for yellow. The parents would be written as *Gg* and *Gg*. Crossing the parents would result in offspring as shown in the following Punnett square. Offspring have pairs of factors *GG* or *gg*, but the parents have only *Gg*.

	G	*g*
G	*GG*	*Gg*
g	*Gg*	*gg*

Two traits are required to illustrate Mendel's second law. An example that illustrates Mendel's second law are the traits of green and yellow pods (*Gg*) and round and wrinkled seeds (*Rr*). The Punnett square for these traits would be as follows.

	GR	*Gr*	*gR*	*gr*
GR	*GGRR*	*GGRr*	*GgRR*	*GgRr*
Gr	*GGRr*	*GGrr*	*GgRr*	*Ggrr*
gR	*GgRR*	*GgRr*	*ggRR*	*ggRr*
gr	*GgRr*	*Ggrr*	*ggRr*	*ggrr*

Note: Any parental cross could be shown with the use of the Punnett square where one trait would be *A* and the other *B*. Dominance and recessiveness would be expressed as *AaBb*.

Section 1: Activity 3

1. When there are more than two possible alleles for any trait, the term *multiple alleles* is used to describe this condition. The ABO blood-typing system shows three alleles for blood cell antigens (proteins on the cell surface). Allele I^A produces antigen A; allele I^B produces antigen B; and allele *i*, which is recessive, produces no antigen.

2. When two alleles express themselves in the phenotype, they are said to be codominant. Neither masks the other. This condition is observed in the ABO blood type system.

3. If each parent is heterozygous, then this is possible.

   If P_1: female ♀ $I^A i \times$ male ♂ $I^B i$,

   then F_1: 1 *ii* (only possible if each parent is heterozygous)

   1 $I^A I^B$ (one allele inherited from each parent)

   1 $I^A i$ (one allele inherited from each parent)

   Note: One $I^B i$ is also possible according to the following Punnett square.

	I^B	*i*
I^A	$I^A I^B$	$I^A i$
i	$I^B i$	*ii*

Genotype:	$I^A I^B$	$I^A i$	$I^B i$	*ii*	
Phenotypic Ratio:	$\frac{1}{4}$:	$\frac{1}{4}$:	$\frac{1}{4}$:	$\frac{1}{4}$	or 1:1:1:1
Blood Type:	AB	A	B	O	
Probability:	0.25	0.25	0.25	0.25	

4. Blood type O is the result of the absence of a dominant allele, both I^A and I^B. Therefore, the homozygous recessive condition of *ii* will produce blood type O.

5. Only one pair of chromosomes determines gender. (The other 22 pairs are called autosomes and are common to males and females.)

6. Male ♂ : XY Female ♀ : XX

7.

	X	X
X	XX	XX
Y	XY	XY

Genotypes	XY		XX
Phenotypic Ratio:	$\frac{2}{4}$	:	$\frac{2}{4}$
	Male		Female
Probability:	0.5		0.5

8. Sex-linked traits are ones where the gene determining the trait is found on the X-chromosome. Examples of such traits include colour blindness, hemophilia, and optic atrophy (a degeneration of nerves in the eye). Traits that are carried by both but only expressed in one of the two genders, like milk production in dairy cows, are called sex-limited. Finally, sex-influenced traits are found in both genders, but are more commonly expressed in one of the two, like baldness in human males.

9. **Textbook question 1:**

Mother ♀

Father ♂		X^c	X^c
	X^C	$X^C X^c$	$X^C X^c$
	Y	$X^c Y$	$X^c Y$

Note: Your textbook (Figure 3.10) does not show the X chromosome in the Punnett square. It is included here to remind you that the gene is found on that chromosome.

Genotypes	$X^C X^c$		$X^c Y$
Phenotypic Ratio:	$\frac{2}{4}$	:	$\frac{2}{4}$
	Normal Female		Colour blind Male
Probability:	0.5		0.5

All daughters are normal, so the probability of a daughter being colour blind is zero. All sons are colour blind, so the probability of a son being colour blind is one.

	X^C	X^c ← daughter
X^c	$X^C X^c$	$X^c X^c$
Y	$X^C Y$	$X^c Y$

↑ spouse

Genotypes:	$X^C X^c$		$X^c X^c$		$X^C Y$		$X^c Y$
Phenotypic Ratio:	$\frac{1}{4}$	:	$\frac{1}{4}$	:	$\frac{1}{4}$	:	$\frac{1}{4}$
	Normal Female		Colour blind Female		Normal Male		Colour blind Male
Probability:	0.25		0.25		0.25		0.25

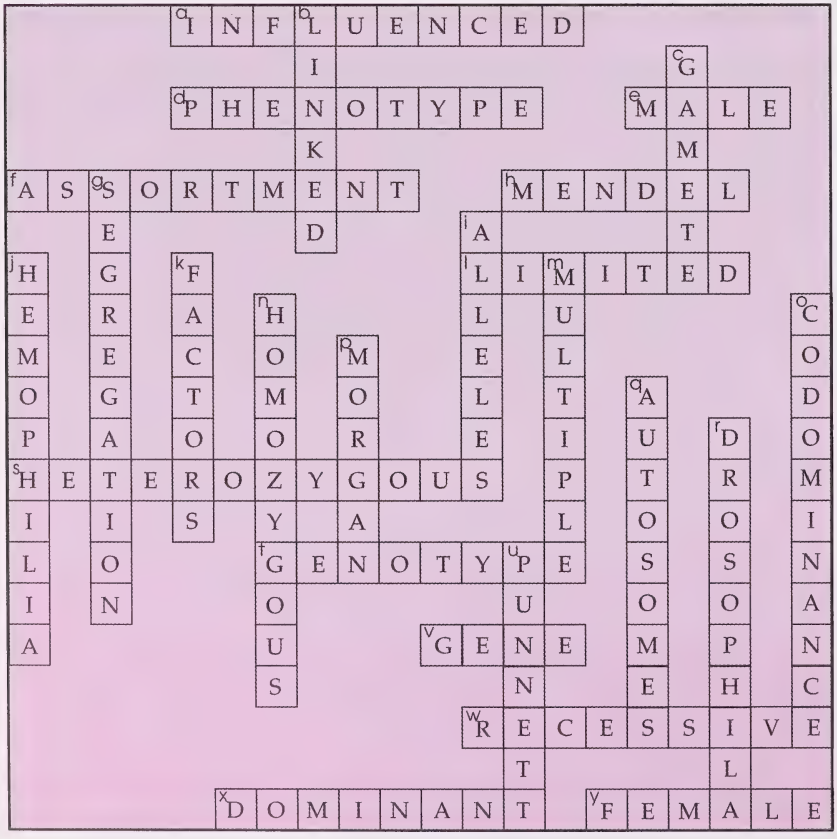
The probability that a daughter of this marriage will be colour blind is 0.50. (Half of the daughters born will be colour blind.) The probability that a son of this marriage will be colour blind is also 0.50. (Half of the sons born are colour blind.)

Textbook question 2: The woman's genotype is $X^c X^c$ because she is colour blind. Her mother's genotype is $X^C X^c$ because she is not colour blind but did pass on a colour blindness gene to her daughter (the mother is a carrier). Her father's genotype is $X^c Y$. Her father must be colour blind because the X chromosome he gave to his daugher contained a gene for colour blindness.

Section 1: Follow-up Activities

Extra Help

1.



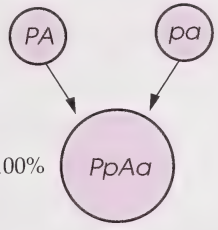
2. **Textbook question 2:** The genotype is *Pp*. Heterozygotes have two different alleles for the trait.

   Textbook question 3: Wrinkled seeds is a recessive condition, so the plant must be homozygous for it to be expressed.

   Textbook question 4:
   The genotype is *Tt* which is heterozygous.
   The phenotype is tall. The dominant allele expresses itself over the recessive allele in the trait.

3. Any letters could be used to represent the genes. If purple is *P* and white is *p*, and axial is *A* and terminal is *a*, then the results would be as follows.

   P_1: *PPAA* × *ppaa*
   Phenotypes: purple, axial white, terminal
   Gametes:



   F_1: 100%

   Phenotype: purple, axial
   F_2: The results of a cross between two F_1 individuals will be the dihybrid cross results.

Phenotypes:	purple, axial	purple, terminal	white, axial	white, terminal
Ratio:	$\frac{9}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{16}$
Probabilities:	0.56	0.19	0.19	0.06

4. Refer to Table 3.2 on page 84 in your text.

5. Since the gene for hemophilia is found only on the X-chromosome, the man will be able to transmit this to each of his daughters. He transmits the Y-chromosome to his sons.

	$X^?$	$X^?$
X^h	$X^?X^h$	$X^?X^h$
Y	$X^?Y$	$X^?Y$

   Alleles from the mother do not matter in this problem.
   Only daughters get the X^h chromosome.
   No X-chromosome is given to the sons from the father.

6. As previously shown, a dominant allele on one X-chromosome would be transmitted from a mother to half of her sons and half of her daughters or from a father to all of his daughters. Therefore, it would show more commonly in the females.

Enrichment

1. **Textbook question 2:** Chromosomes follow the law of independent assortment. All genes on a chromosome are linked together and will be transmitted together. However, genes that are on different chromosomes will follow Mendel's law of independent assortment. You will learn more about this in the next section when you are introduced to meiosis.

Textbook question 3: The explanation is that some alleles are incompletely dominant. A heterozygous condition produces a "blended" phenotype. Assume the *B* = black-feathered and *W* = white-feathered. The homozygous *BB* would be black and *WW* would be white. However, the heterozygous *BW* would now be a "blend" or blue.

Textbook question 4: This is a simple one-trait condition and will follow Mendel's law of segregation. The probability that a son would have an index finger shorter than a ring finger is 0.75, while the probability for a daughter to have this condition is 0.25.

2. The following chart shows which transfusions are possible and which are not.

Recipient Type (antibodies) / Donor Type (red blood cells)	A (anti B)	B (anti A)	AB (no antibody)	O (anti A and B)
A (antigen A)	✓	X (clumping)	✓	X (clumping)
B (antigen B)	X (clumping)	✓	✓	X (clumping)
AB (antigen A and B)	X (clumping)	X (clumping)	✓	X (clumping)
O (no antigen)	✓	✓	✓	✓

Type AB is the universal recipient because neither antigen is foreign and there is no antibody to clump the red blood cells. Type O is the universal donor because it has no antigen on its red blood cells and cannot be identified as being foreign.

3. Use your local public library. Recording your findings using the following headings.

- name of the condition
- brief history of the study of the trait
- symptoms of the condition
- recent research
- prognosis for the future

You may wish to choose a disorder that is found in your family.

4. a. Your results may be similar to these.

Week 1: Parental flies selected had the following trait combinations.
Phenotype → normal-winged, red-eyed × vestigial-winged, sepia-eyed
Genotype → $v^+v^+s^+s^+$ $v\,v\,s\,s$

Week 2: F_1 generation flies all have the same genotpye and phenotype.
Phenotype → normal-winged, red-eyed
Genotype → $v^+v\,s^+s$
(Since normal wings and red eyes are dominant and one allele of each trait comes from each parent, all F_1 generation flies are normal-winged, red-eyed.)

Week 3: F_2 flies are growing during this week.

Week 4: F_2 generation flies have the phenotypes normal-winged, red-eyed; normal-winged, sepia-eyed; vestigial-winged, red-eyed; and vestigial-winged, sepia-eyed. Your actual numbers will vary from the ones given here but the ratio should be approximately 9:3:3:1. For example, you might have recorded the numbers of F_2 generation flies as 90, 30, 30, and 10. In this case $\frac{90}{160}$ or $\frac{9}{16}$ are normal-winged, red-eyed; $\frac{30}{160}$ or $\frac{3}{16}$ are normal-winged, sepia-eyed; $\frac{30}{160}$ or $\frac{3}{16}$ are vestigial-winged, red-eyed; and $\frac{10}{160}$ or $\frac{1}{16}$ are vestigial-winged, sepia-eyed. The genotype is given by the following Punnett square.

b. Your answers should be similar to the following. The predicted and actual are sample results. You may not have the same parent phenotype or F_1 phenotype in your results.

Textbook question 1:

Punnett Square for the Dihybrid Cross

	v^+s^+	v^+s	vs^+	vs
v^+s^+	$v^+v^+s^+s^+$	$v^+v^+s^+s$	$v^+vs^+s^+$	v^+vs^+s
v^+s	$v^+v^+s^+s$	v^+v^+ss	v^+vs^+s	v^+vss
vs^+	$v^+vs^+s^+$	v^+vs^+s	vvs^+s^+	vvs^+s
vs	v^+vs^+s	v^+vss	vvs^+s	$vvss$

→ $v^+\_\_s^+\_\_$ = normal-winged, red-eyed = $\frac{9}{16}$

→ $v^+\_\_s\,s$ = normal-winged, sepia-eyed = $\frac{3}{16}$

→ $v\,v\,s^+\_\_$ = vestigial-winged, red-eyed = $\frac{3}{16}$

→ $v\,v\,s\,s$ = vestigial-winged, sepia-eyed = $\frac{1}{16}$

Note: Each __ could be a dominant or recessive allele, but does not affect phenotype.

	Normal-winged, red-eyed	Normal-winged, sepia-eyed	Vestigial-winged, red-eyed	Vestigial-winged, sepia-eyed
Predicted F_2	$\frac{90}{160}$	$\frac{30}{160}$	$\frac{30}{160}$	$\frac{10}{160}$
Probability	0.56	0.19	0.19	0.06
Actual F_2	$\frac{151}{255}$	$\frac{47}{255}$	$\frac{58}{255}$	$\frac{9}{255}$
Probability	0.59	0.18	0.23	0.04

Textbook question 2: The experimental results are very close to the predicted probabilities. Any discrepancies could be a result of the same sample size. Both of Mendel's laws are supported by these results. The following information mathematically shows this.

- **One Trait: Law of Segregation**

  Monohybrid Cross: *Aa* × *Aa*

  Offspring: 1 *AA*, 2 *Aa*, 1 *aa* Total = 4

  Phenotypic Ratio: $\frac{3}{4}$ *A*__ : $\frac{1}{4}$ *aa* or 3:1

  Probability: 0.75 0.25

  Actual Results: normal-winged vestigial-winged

  151 + 47 58 + 9 Total = 265

  $\frac{198}{265}$ $\frac{67}{265}$

  Calculated Probability: 0.75 0.25

  Actual Results: red-eyed sepia-eyed

  151 + 58 47 + 9 Total = 265

  $\frac{209}{265}$ $\frac{56}{265}$

  Calculated Probability: 0.79 0.21

- **Two Trait: Law of Independent Assortment**

  Dihybrid Cross: *AaBb* × *AaBb*

  A__B__, *A__bb*, *aaB__*, *aabb*

  Phenotypic Ratio: $\frac{9}{16}$: $\frac{3}{16}$: $\frac{3}{16}$: $\frac{1}{16}$ or 9:3:3:1

  Probability: 0.56 0.19 0.19 0.06

  Actual Results: (normal-winged, red-eyed) (normal-winged, sepia-eyed) (vestigial-winged, red-eyed) (vestigial-winged, sepia-eyed)

  Calculated Probability: 0.59 0.18 0.23 0.04

c. The F_2 result would be the same. The sex of the parent makes no difference in the transfer of these traits.

Section 2: Activity 1

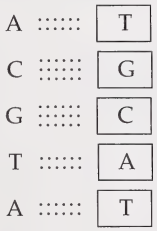
1. Avery and his co-workers proved that DNA is the hereditary molecule that controls the inheritance of traits in organisms. Deoxyribonucleic acid (DNA) is found in the nucleus of every cell. It is the master code for cellular processes.

2. Nobel Prize winners James Watson and Francis Crick discovered the chemical structure of DNA. This helped explain many of the characteristics of the complex double molecule and helped unlock the mystery of how DNA controls the activity of a cell.

3. The basic unit of DNA is a nucleotide. It is composed of a **deoxyribose** sugar, a **phosphate**, and one of four nitrogenous **bases**, which bond together to form the double helix shown in Figure 3.12 on page 98 in your text.

4. A (Adenine) bonds only with T (Thymine). There are two hydrogen bonds bonding these bases.
G (Guanine) bonds only with C (Cytosine). There are three hydrogen bonds bonding these bases. In this way the sequence of base pairings is exact and can be copied and passed on.

5. Your answer should show exact base pairing.



6. For new cells to have a complete and functioning set of genetic information, a cell must be able to duplicate its DNA exactly. It must be able to create two identical copies of its DNA.

7. When the hydrogen bonds between complementary bases break and the double helix unwinds, bases are exposed. New bases can fill in the openings according to the specific base pairing rules you have already learned $(A = T, C \equiv G)$. In this way, two identical DNA molecules are created with exactly the same sequence of bases. This process is called replication. See Figure 3.13 on page 99 of *Visions 3*.

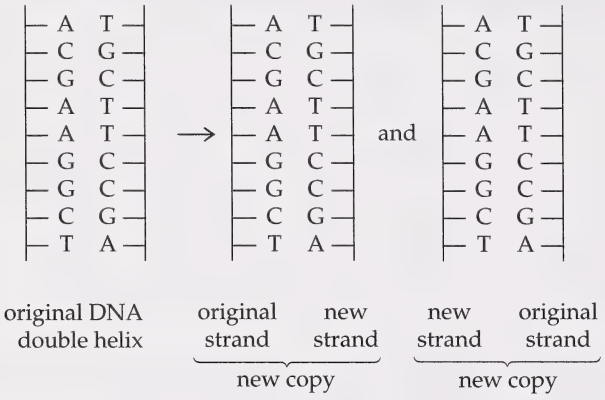
8. In order to copy the genetic code and get the message to the ribosomes of the cytoplasm where protein synthesis takes place, the DNA must be transcribed. Transcription is the process by which the genetic code is transferred from the DNA molecule to the messenger RNA molecule. See Figure 3.14 on page 100 of *Visions 3*. The double helix first unzips (like it does during replication). Instead of DNA nucleotides filling the openings, RNA (ribonucleic acid) nucleotides take their place. The base pairing rules stay the same except in the case of T (Thymine). This base does not bond to ribose sugar, but instead, the base U (Uracil) will take its place. This means that each A (Adenine) in the DNA will now bond to a U (Uracil) in the RNA. Transcription is complete when a strand of messenger RNA is produced from a gene (which is a portion of the DNA code). RNA translation occurs in the ribosomes of the cytoplasm. It is a process that involves the mRNA (messenger RNA) and special transfer RNA molecules. These transfer RNA carriers bring specific amino acids to the ribosome. Every three bases (codon) of the mRNA signify a specific amino acid to be brought to the ribosome by a transfer RNA. In this way each codon of the genetic code represents a specific amino acid. The type of protein that is produced is determined by the sequence of amino acids that are bonded together in the ribosome. Therefore, the sequence of bases in DNA really determines the sequence of amino acids in proteins. The proteins of a cell determine its traits.

9. A full complement of DNA is two sets of chromosomes. Chromosomes are made up of DNA. These chromosomes are inherited from parents, one full set from the male (father) and the other full set from the female (mother). The two sets of DNA will produce the genetic traits that were explained by Mendel and other geneticists.

10. The purines found are adenine and guanine. The pyrimidines found are thymine and cytosine. In RNA, uracil is the pyrimidine that replaces thymine.

11. The sequence of events in DNA replication are as follows:

    - DNA double helix unzips when hydrogen bonds break.
    - Free floating nucleotides bond to exposed nucleotides.
    - Purines bond to pyrimidines in a specific order $A = T$ and $G \equiv C$.
    - Sugar-phosphate bonds link individual nucleotides.
    - The completed process produces two identical copies of DNA as shown:



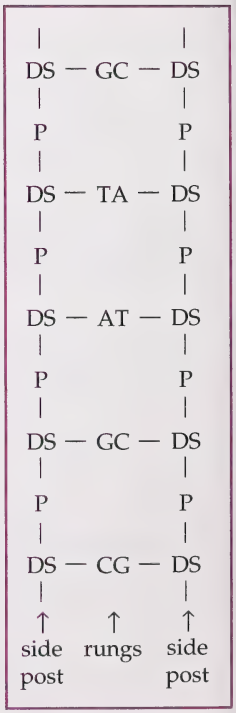
    The two new DNA molecules are identical and can be distributed to each new cell after division.

12. The DNA ladder is organized for you in the answer to question 11. The side posts are alternating deoxyribose sugars and phosphates. The rungs are formed from complementary base pairings.

13. Since each codon has three nucleotide bases, there are two codons in your six-nucleotide sequence.

14. The colour sequences will vary depending on which bases you selected for your original DNA molecule. However, the two new DNA molecules will have identical sequences and these colours will match the sequence of the original strands of DNA.

15. The original sequence is the template or mold for the new sequence because the bases pair in specific order.



16. The ladder would not fit. The rungs would be too long if adenine bonded with guanine. These double-ringed purines would alter the shape of the ladder. If adenine bonded to cytosine the rung would fit, but the original sequence would now be different. A mutation would be the result.

17. A strand of mRNA would differ in the sugar (ribose instead of deoxyribose) and one base (uracil instead of thymine). Otherwise, the phosphate is the same and the bases adenine, guanine, and cytosine are the same.

18.

DNA	TAC	TTC	GCA	ATA	CCG	AGC
mRNA	AUG	AAG	CGU	UAU	GGC	UCG

19.

mRNA	AUG	AUC	AAU	GAU	GAG	UGU
Protein (amino acid chain)	methionine	isoleucine	asparagine	aspartic acid	glutamic acid	cysteine

Section 2: Activity 2

1. Both of these biologists observed that the movement of chromosomes during cell division followed the patterns presented by Mendel. This explains in a clear and concise manner how genes for certain traits are passed from parents to offspring.

2. The cell's life cycle begins with Gap 1 (G_1) when it starts to grow. DNA transcription, RNA translation, and protein synthesis allow the cell to start to express its traits. Then, Synthesis (S) of DNA occurs as each DNA molecule is replicated. This produces sister chromatids that have identical sequences of nucleotides. Essentially, they are copies of the old DNA. This is followed by Gap 2 (G_2) where the centrioles, spindle fibres, and any structures needed for cell division are readied as the cell prepares for division. Finally, mitosis (M) begins and the nucleus divides producing identical copies at either end of the parent cell.

3. The correct organization will be

   Prophase—c Metaphase—a Anaphase—d Telophase—b

4. a. Cytokinesis occurs during the telophase.
   b. As the cytoplasm divides, the cell membrane pinches the parent cell into two new cells.
   c. Interphase is simply the part of the cell's life cycle when it is not dividing. It includes G_1, S, and G_2.

5. Each phase will be similar to those in Figure 3.6 on page 86 in your text. Study both the photographs and the drawings in Figure 3.6. Plant cells, however, do not have centrioles and the spindle may be difficult to see.

6. Sample data may be similar to yours.

Total Cells	Interphase	Prophase	Metaphase	Anaphase	Telophase
60	30	15	2	3	10

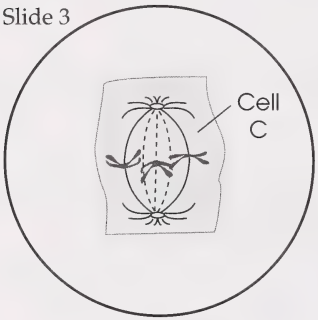
7. The tip of the root grows the fastest, so the cell cycle will be very short. New cells are produced quickly and many should be in one of the phases of mitosis.

8. Using the same data from question 6, the 30 cells in active cell division would represent the 1 hour of mitosis. The following chart shows the estimated time.

Total Cells	Interphase	Prophase	Metaphase	Anaphase	Telophase
60	30	15	2	3	10
Total Time		30 min	4 min	6 min	20 min
120 min	60 min	60 min			

9. Without a complete set of chromosomes a cell would not function normally at all. The full genetic code could not be expressed and many abnormalities may occur. These may include no mitosis, no DNA replication, or altered protein synthesis.

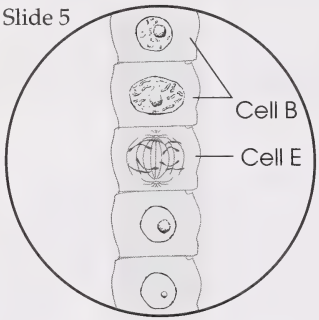
10. Slide 3



Metaphase

Chromatid pairs are aligned across the equator of the spindle.

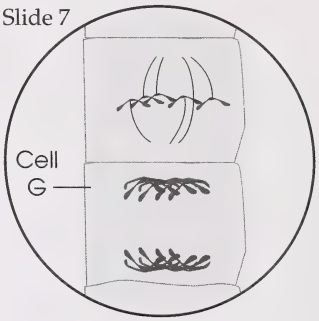
Slide 5



Anaphase

Chromatid pairs are segregating from each other and moving toward opposite poles.

Slide 7



Telophase

Chromosomes are tightly packed at opposite poles.

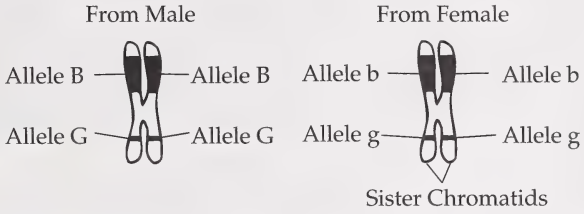
11. The cell cycle is like a motion picture. Different cells are at different parts of the cycle. When a slide is made, the movie is stopped at one point. Since interphase is the longest part of the cycle, there will be the most cells in that phase. In mitosis, prophase and telophase are the longest, so there should be more cells showing these phases. Metaphase and anaphase are very short, so there will be very few cells in these phases of mitosis.

Section 2: Activity 3

1. Homologous pairs of sister chromatids are identified by having the same banding. This represents the same sequence of genes on the chromosomes. **Note:** One homolog comes from the father and the other homolog comes from the mother.

   Homologous pairs, therefore, are 1-C, 2-E, 3-B, 4-A, 5-D.

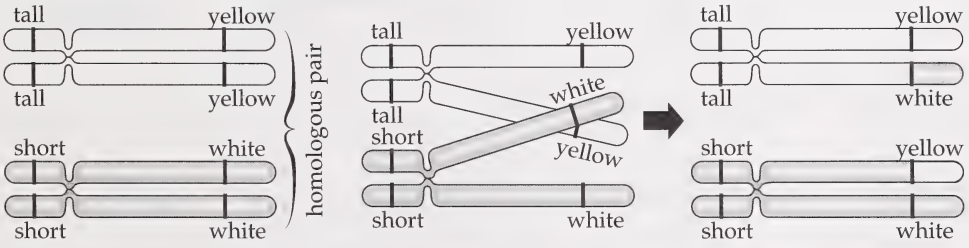
Example of a Homologous Pair of Chromosomes with Sister Chromatids



Homologous chromosomes will carry the same sequence of genes, but not necessarily identical alleles for a specific gene (allele B on one homolog and allele b on the other).

Sister chromatids are produced by DNA replication; thus, they have identical information (allele b on both chromatids).

2. During synapsis when homologous pairs of chromosomes, each comprised of sister chromatids, align together, it is possible for pieces of the chromosomes to cross over. This creates a new linkage of genetic information, even though the sequence of genes remains the same. The following illustration shows the result of crossing over and the new combinations.



3. During meiosis I, at metaphase, homologous chromosomes (each comprised of two sister chromatids) line up across from each other on the equatorial plane. One of this pair of homologous chromosomes is pulled by spindle fibres to one daughter cell, while the other homolog of each pair is pulled to the other daughter cell. During metaphase of mitosis, you will remember, all chromosomes line up individually on the equatorial plane, and spindle fibres pull sister chromatids to opposite daughter cells.

4. During meiosis II, the sister chromatids of each chromosome separate and go to different daughter cells.

5. a. DNA of chromsosomes is replicated both before mitosis and before meiosis I. The same basic stages (prophase, metaphase, anaphase, telophase) occur in each process.

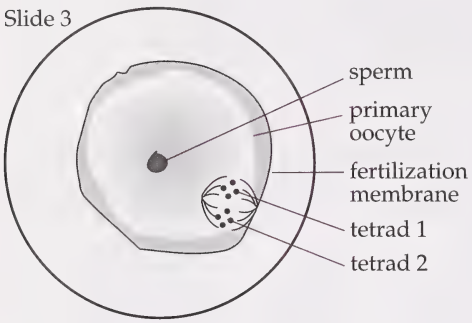
   b. Meiosis involves the stages of cell division being performed twice, once to separate homologous chromosome pairs (meiosis), and once to separate the chromatids of each individual chromosome (meiosis II). Meiosis I involves the synapsis of homologous chromosomes, which does not occur in mitosis. This synapsis may lead to "crossing over" which increases variability in the genotypes possible in gametes. The main difference is that the cells produced by mitosis are diploid (2n) and identical to the parent cell. The cells produced by meiosis are haploid (n) gametes.

6. a. In human males a single parent cell results in four sperm cells and the production of sperm cells is continuous. In human females one parent cell results in only one functional cell (ovum). The other three cells from the meiotic process do not develop as functional ovum.

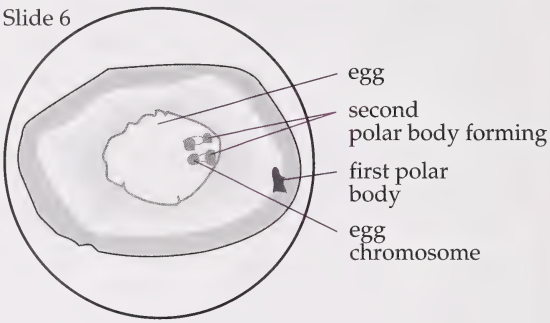
   b. During fertilization, a sperm and an egg unite. This fusion of nuclei will restore the normal pairing of homologous chromosomes by producing a diploid zygote (2n). The genetic variation in the gametes, which resulted from independent assortment and possibly some crossing over, will now be transmitted to the new organism.

7. Meiosis I accomplishes the same as mitosis, except the sister chromatids may be different as a result of crossing over. Meiosis II will produce gametes or haploid cells from the diploid meiosis I or mitosis cells.

8. Slide 3



Slide 6



9. The parts labelled T_1 and T_2 are called tetrads because they are each composed of four parts. The prefix *tretr* means four.

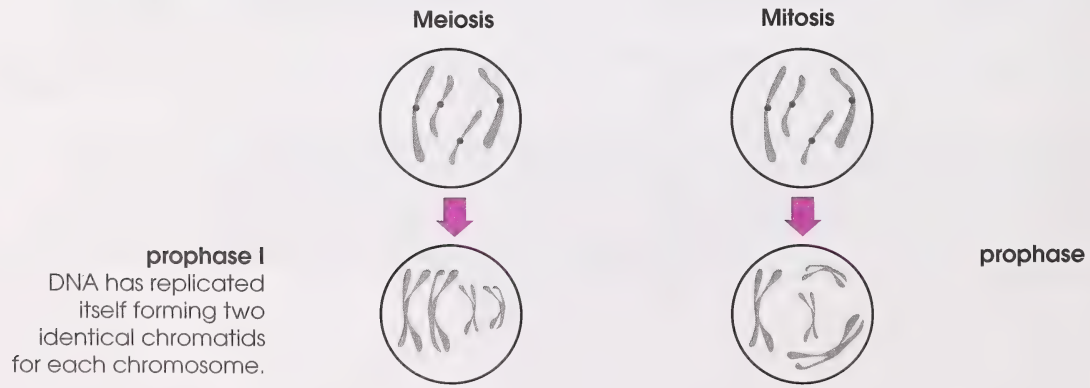
10. The chromosomes in Slide 3 appear to be lined up along an equatorial line.

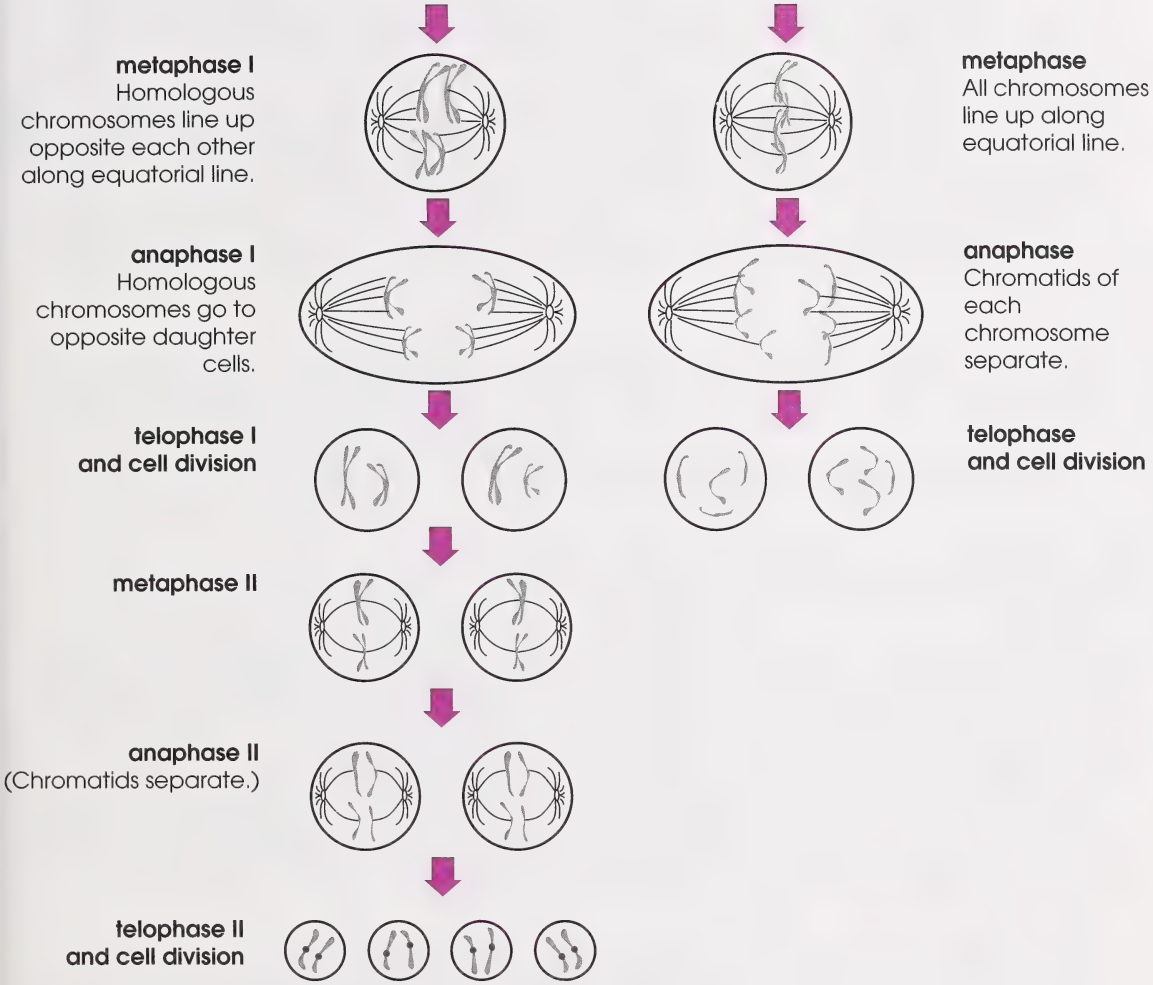
11. Slides 1 to 4 most likely show various stages of meiosis I. Slide 5 shows the start of meiosis II.

12. The chromosomes that separate and move out of the cell become part of the polar bodies.

13. The polar bodies die and disintegrate harmlessly.

14. Your completed drawings should look like this.





The four differences between mitosis and meiosis are as follows:

- Homologous chromosomes pair (synapsis) during prophase I of meiosis; there is no pairing of chromosomes in mitosis.
- Mitosis involves a single division into two diploid nuclei; meiosis involves two successive divisions resulting in four haploid nuclei.
- DNA replicates before each mitotic division; DNA replicates before the first meiotic division but not the second.
- Mitosis produces two daughter nuclei with genetic information identical to that of the parent nucleus; the four haploid nuclei produced by meiosis contain only half of the genetic information that was present in the parent cells.

Section 2: Follow-up Activities

Extra Help

1. Adenine is a double-ring base that forms two hydrogen bonds. Only thymine is a single-ring base that also forms two hydrogen bonds. Guanine is a double-ring base that forms three hydrogen bonds. Only cytosine is a single-ring base that also forms three hydrogen bonds. Therefore, the base pairing rule is A = T and G ≡ C in DNA.

2. There are six split base pairs shown. If every three base pairs is a codon, then this gene would have two codons.

3. RNA polymerase causes the DNA to unzip and allows complementary RNA nucleotides to bind to the DNA template or blueprint. The enzyme binds the RNA nucleotides together between the ribose sugar and the phosphate producing a strand of messenger RNA. This process allows copies of the DNA code (genes) to leave the nucleus and control cell activity by synthesizing proteins in ribosomes of the cytoplasm.

4. a. Lysine is specified by the AAG codon of mRNA.

   b. Phenylalanine is specified by the UUU codon of mRNA.

   c. Glycine is specified by the GGA and GGC codons of mRNA.

5. Cell A begins to grow as a result of DNA **transcription**, which produces mRNA molecules for each of the active genes. The ribosomes will be the site of RNA **translation** and protein synthesis, so active genes can produce traits in maturing cells.

6. By the time mitosis begins, Cell A will have replicated its DNA and produce sister **chromatids** for each of the **homologous** chromosomes present. During **prophase** the spindle begins to form and the chromatids are visible. The centromeres attach to spindle fibres and align all of the chromatid pairs at the equator during **metaphase**. Separation of the chromatid pairs during **anaphase** allows new Cells B and C to receive the same genetic information as Cell A had. Nuclear division or mitosis is completed during **telophase** and **cytokinesis** will divide Cell A into Cells B and C.

7. If Cell B were then to grow to maturity, replicate its chromosomes and undergo meiosis, then during meiosis I the chromosomes of Cell B would align in tetrads or pairs of homologs. This is called **synapsis** and may allow chromatids to exchange genetic information in a process called **crossing over**. Homologous chromosomes will separate during **anaphase** I of meiosis. In meiosis II, the chromatids of each chromosome will separate to produce **gametes**. The union of male and female gametes produces a **zygote** and ensures genetic variation in the offspring of organisms.

8. When Cell B occurs in a male, there are four gametes or sperm produced as illustrated (D_1, D_2, D_3, D_4). However, if Cell B was produced in a female, then formation of gametes would produce only one egg cell.

Enrichment

1. DNA will not replicate if it cannot unzip. Transcription will also stop. Both of these events will ultimately lead the cell to die.

2. You can research this topic at your local library or contact the RCMP or local police agency in your area. DNA fingerprinting can also be used in paternity lawsuits or in locating and identifying lost or missing children.

3. The DNA of identical twins should be exactly the same. This would mean that they produce the same proteins and types of tissue.

4. Little variation would exist in the plant world. All roses, for example, might come from the same parents. Any new disease would impact on all roses in the same way. There would never be any improvements in seed production, flowering, or growth patterns.

Section 3: Activity 1

1. A gene pool contains all the alleles for all the genes carried by all the individuals in a breeding population. It is like an ocean of DNA for the population.

2. Hardy and Weinberg discovered that the frequency of alleles for observable traits will remain constant if the population is stable, that is, if no evolution is occurring in the population. They reduced their findings to some mathematic formulae.

3. From what you have learned in Section 1, it is logical to assume that the dominant phenotypes will be more common than the recessive phenotypes. This occurs because both *AA* and *Aa* genotypes will produce the dominant phenotype, while only *aa* produces the recessive phenotype.

4. There are numerous traits that cannot be explained only on the basis of dominant and recessive alleles. You know that multiple alleles produce some variable circumstances. Also, sex-linked, sex-influenced, and sex-limited traits will not conform exactly to the patterns produced by dominant and recessive alleles.

5. If the frequency of the recessive allele is 0.17
and $p+q=1$ and $q=0.17$,
then $p=1-0.17=0.83$ (spotted coat frequency).

6. If p^2 + $2pq$ + q^2 = 1

↓	↓	↓	↓
AA, spotted	2*Aa*, spotted	*aa* black	Whole population

then $q^2=(0.17)^2=0.0289$
and $0.0289\times100\%=2.89\%$
Therefore, 2.89% of leopards in an area would be black.

7. From the information in the preceding question, the carriers are represented by $2pq$.
Therefore, $2\times0.83\times0.17=0.28$ (frequency of heterozygotes)
and $0.28\times1000=280$ (heterozygotes in population).
Thus, 280 leopards in a population of 1000 leopards would be carriers for the recessive allele.

8. Your chart should look like this.

A Characteristic	B Dominant Phenotype (Number)	C Recessive Phenotype (Number)	D Total Survey (Number)	E Fraction with Dominant Phenotype (B/D)	F Fraction with Recessive Phenotype (C/D)	G Fraction with Recessive Allele Frequency $(\sqrt{F})$	H Fraction with Dominant Allele Frequency (1-G)
Ear Lobe Shape							
Mid-digital Hair							
Tongue Rolling							
Widow's Peak							
PTC Tasting	8	2	10	$\frac{8}{10}=0.8$	$\frac{2}{10}=0.2$	0.4	0.6
Interlacing Fingers							
Colour blindness (male)							
Colour blindness (female)							

The data you collect will vary somewhat, but the frequencies of recessive allele and dominant allele will add up to approximately 1.

9. **Textbook question 1:** The relationship between p (frequency of the dominant allele) and p^2+2pq (frequency of the dominant phenotype) is quite obvious from the mathematical model.

For the example of PTC tasting: $p=0.8$ and $p^2+2pq=(0.8)^2+2(0.8)(0.2)$

$$=0.64+0.32$$

$$=0.96$$

The frequency of the dominant phenotype is close to 1. The dominant phenotype occurs more frequently than the recessive phenotype. Your predictions should have been verified. Your paragraph should include the concepts presented on the mathematical methods used by Hardy and Weinberg to describe the frequencies of dominant and recessive alleles in a stable, non-evolving population.

Textbook question 2: In a large enough sample you would find that 2.4% of the males are colour blind, while only 0.8% of the females are colour blind. You would probably have hypothesized that this trait is found on the X-chromosome and the frequencies are linked to gender.

10. The mathematical model helps you calculate the frequencies of each of the possible genotypes for a trait in the population. Once again, the summary of this is as follows.

p^2	+	$2pq$	+	q^2	=	1
↓		↓		↓		↓
Homozygous dominant genotype (AA)		Heterozygous genotype (Aa)		Homozygous recessive genotype (aa)		Total population

The model is also useful in showing if evolution or trait change is occurring in a population. If the values for p and q for a population do change significantly over time, one knows the makeup of the gene pool is changing and evolution or trait change is occurring.

Section 3: Activity 2

1. The two sets of homologous pairs of sister chromatids formed in prophase of meiosis I segregate during anaphase of meiosis I. The pairs of sister chromatids that align to the equator during metaphase of meiosis II will segregate during anaphase of meiosis II. Therefore, chromosome pairs separate at two times during meiosis.

2. If the chromosome pairs do not "disjoin," the resulting cells will have an abnormal number of chromosomes. Abnormal gametes that unite during fertilization will lead to abnormal offspring.

3. This abnormal condition results from nondisjunction of the 21st pair of chromosomes. The egg may most likely be the site of this abnormal chromosome activity. Whether nondisjunction occurs during meiosis I or meiosis II, the egg ends up with two number 21 chromosomes instead of one. Union with a normal sperm will result in three number 21 chromosomes and this causes Down Syndrome.

4. Dr. Martin reports that normal men have a 10% frequency of chromosomal abnormalities in their sperm. This frequency can increase as a result of radiotherapy or long-term exposure to certain environmental factors. Her research will help pinpoint probable causes for abnormalities.

5. Chromosome pair 4 is longer, has different shapes, and has different banding (gene sequences) than chromosome pair 19.

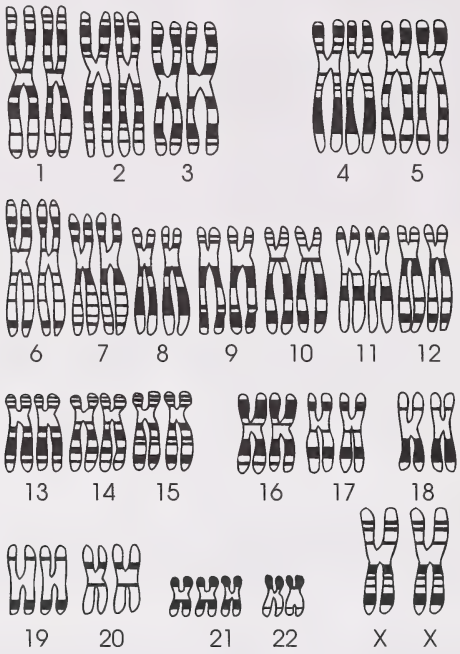
6. The individual in the human karyotype chart is male because the sex chromosomes are heterozygous (XY).

7. Individual A has 47 chromosomes.

8. Since the sex chromosomes (chromosome pair 23) are homozygous (XX), Individual A is female.

9. Your karyotype should look like this.

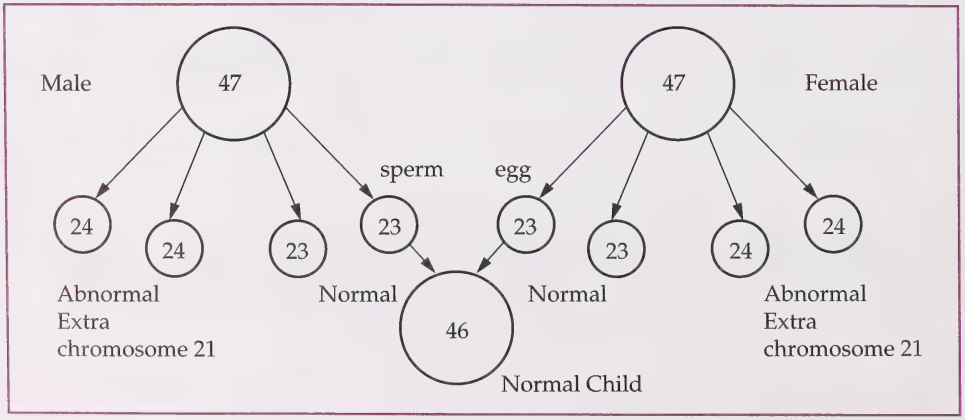
Individual A



Since there are three chromosomes in number 21 position, Individual A suffers from Down syndrome.

10. Yes, every cell would have 47 chromosomes because they are all produced by mitosis from the original zygote. Identical copies for an original abnormal cell will produce an organism with 47 chromosomes in every cell.

11. During meiosis, the gametes produced will contain 23 or 24 chromosomes. Normal gametes uniting would result in a normal child. This is illustrated in the following diagram.



Section 3: Activity 3

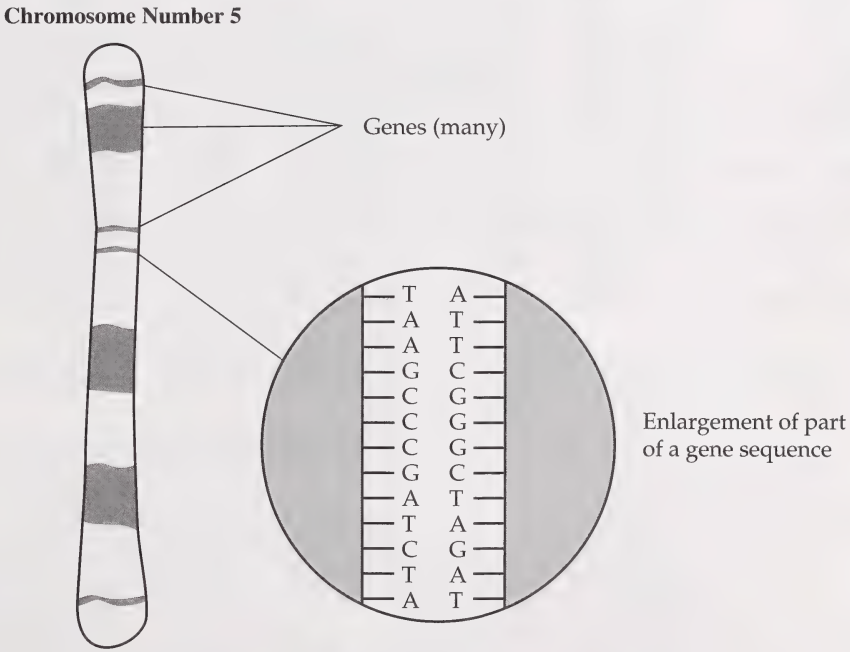
1. Any change in the sequence of bases or codons in DNA will alter the genetic code. The cause of such mutations may be chemicals, ultraviolet light, or radiation. The result will be abnormal functioning of the cell.

2. If the sequence of bases is altered and replicated without correction, all future copies of the DNA will carry the mutation. The affected gene will be transcribed and translated incorrectly. Figure 3.16 on page 102 in your textbook shows just what happens in this case. The 6th codon of the mRNA is mutated. Instead of GAG, it has become GUG. The translation process inserts valine in the position for glutamine. The single change causes the red blood cell to sickle because of mutated hemoglobin molecules.

3. Oncogenes, which can contribute to the development of cancer, are mutations that affect somatic or body cells instead of gametes. Only mutations in the DNA of gametes will be hereditary and passed on from parents to offspring.

4. This well-known disorder is an example of a point mutation in all cells including the gametes. Thus, it is passed on to the offspring.

5. The organization of the genetic code by chromosomes is illustrated as follows:



Each gene is composed of many codons and each codon is made of three base pairs. Therefore, if 1 gene had 90 codons, then it would have 270 base pairs. This would result in $270 \times 100\,000 = 27\,000\,000$ base pairs. However, many genes have far more than 90 codons. The result is that there are far more than 27 000 000 base pairs.

6. James Watson and Francis Crick discovered the base sequencing or pairing for DNA in 1953. The Human Genome Project is trying to sequence all the base pairs in human DNA.

7. These enzymes cut pieces of DNA at specific base pair locations. In this way a gene can be removed. The bacterial plasmid is also cut open by these enzymes allowing the new gene to be inserted into the bacterial DNA.

8. The recombinant plasmid is taken into the bacterium in the presence of calcium. The calcium stimulates the bacteria to take up the plasmids from the medium.

9. When the gene is replicated in the bacterium it behaves exactly the same way it would in the original organism. A gene for human insulin production will make this protein in the bacterium exactly the same as it would in a human. This eliminates any side effects an artificial form of insulin may cause.

10. Applications of recombinant DNA technology include the following:

    - human insulin for diabetics
    - human growth hormone for dwarfism
    - interferons for cancer patients
    - natural herbicides for pest control
    - growth hormone for better feed animals

11. **Textbook question 10:** Cloning a gene is to make many identical copies of the gene.

12. **Textbook question 2:** Answers will vary. Choose a position and support it with a number of points. You might discuss this issue with friends or family. The following is a possible answer.

    Positive points may be as follows:

    - Many abnormalities may be eliminated.
    - Eventually only desirable characteristics may be passed on.

    Negative points may be as follows:

    - making decisions for future generations
    - could lead to selective alteration of gene information
    - difficult to decide who should make such decisions
    - Genetic manupulation might be such that only big or strong or smart human offspring resulted. Is this necessarily beneficial?

Section 3: Follow-up Activities

Extra Help

1. If $q = 0.09$,

   then $q^2 = 0.0081$

   and $q^2 \times 100\,000 = 810$ sickle cell anemics.

2. If $p = 1 - 0.09$,
then $2pq = 2 \times 0.91 \times 0.09 = 0.1638$
and $2pq \times 100\,000 = 16\,380$ carriers.

3. If $p = 1 - 0.09 = 0.91$,
then $p^2 = 0.8281$
and $p^2 \times 100\,000 = 82\,810$ non-carriers.

1	$=$	p^2	$+$	$2pq$	$+$	q^2
Total population		Homozygous dominant (non-carriers)		Heterozygous (carriers)		Homozygous recessive (disorder)
100 000	=	82 810	+	16 380	+	810

4.

a S	E	G	b R	E	G	c A	T	E										
			E			B												
d T			C		e O	N	C	O	G	E	N	E				f R		
H			O			O										E		
E			M		g T	R	I	S	O	M	Y					S		
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Enrichment

1. If $p = i = 0.68, q = I^A = 0.26, r = I^B = 0.06$

   then $p^2 = ii = 0.46$ Type O

   and $q^2 + 2pq = I^A I^A$ and $I^A i = 0.42$ Type A

   and $r^2 + 2pr = I^B I^B$ and $I^B i = 0.04$ Type B

   and $2qr = I^A I^B = 0.03$ Type AB

2. **Textbook question 4:** This syndrome is a result of the following possibilities where nondisjunction occurs.

Egg	Sperm	Zygote
XX	Y	XXY
X	XY	XXY

3. **Textbook question 8:** If the mutation is inherited in a heterozygous condition, then the phenotype will be dominant and the individual will be a carrier for the disorder.

4. **Textbook question 2:** Your research could lead you to a hospital or alternative reproductive technology clinic in your area. These prenatal diagnostic technologies make it possible to detect disorders. This raises legal and ethical issues if something unusual is discovered.

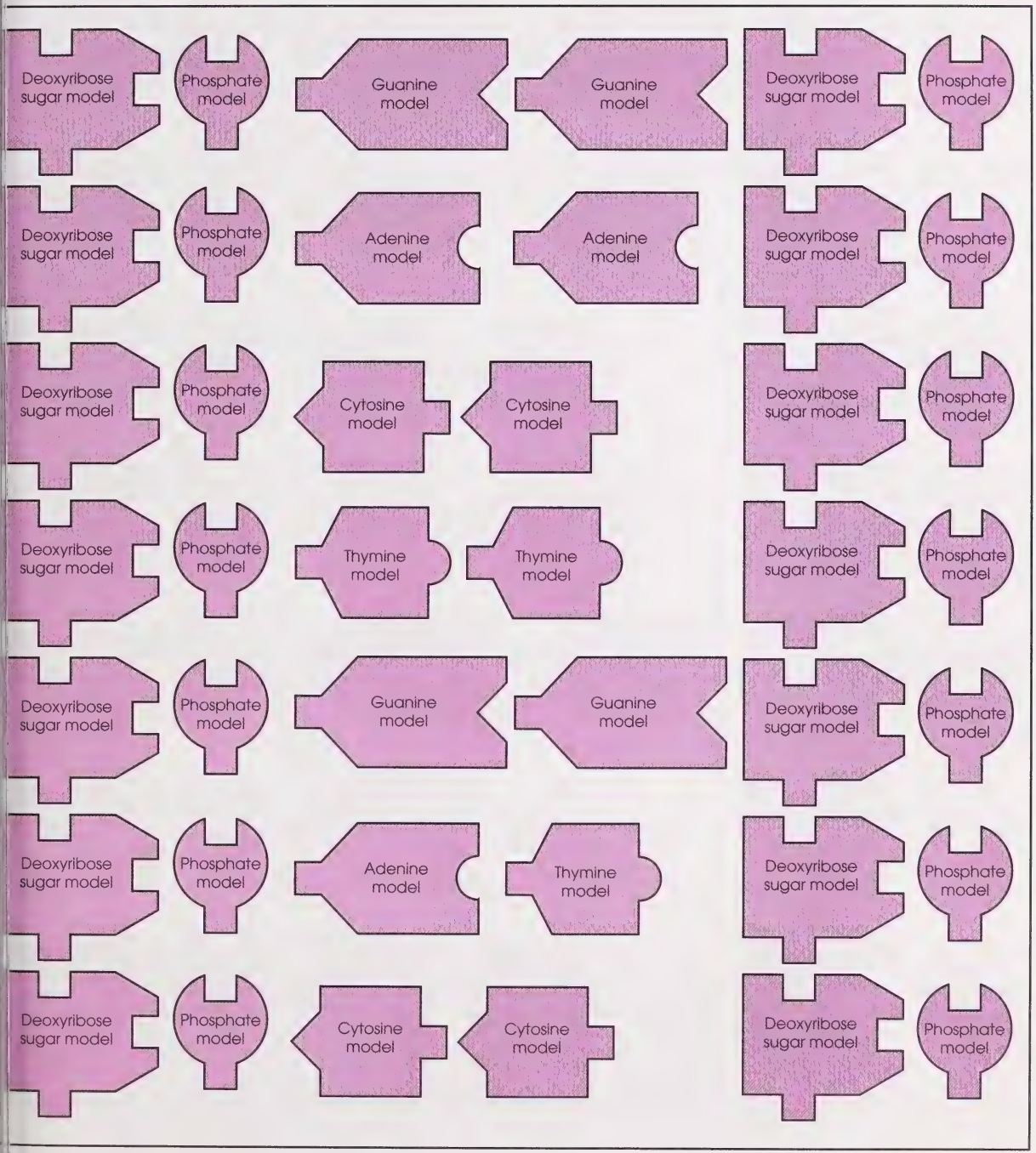
   Amniocentesis—technique of extracting amniotic fluid to examine human karyotypes for nondisjunction

   Chorionic biopsy—technique of extracting cells from the outer membrane surrounding the embryo for chromosomal abnormalities

   Fetoscopy—technique using a fibreoptic camera for direct observation of the fetus to search for phenotypic disorders

   Ultrasonography—technique using sound waves so an x-ray-like image can be produced to examine internal phenotypic disorders.

DNA Symbols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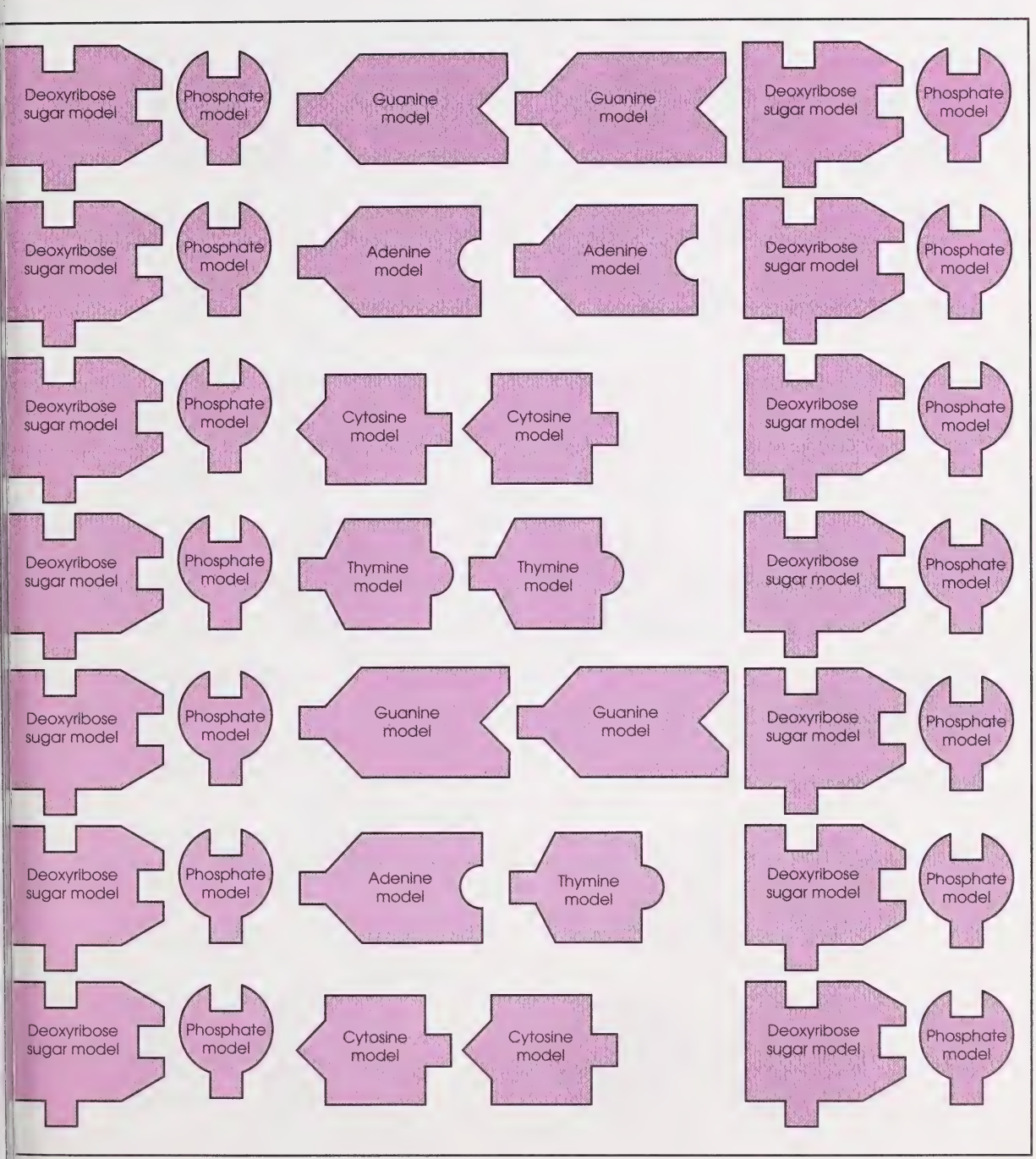
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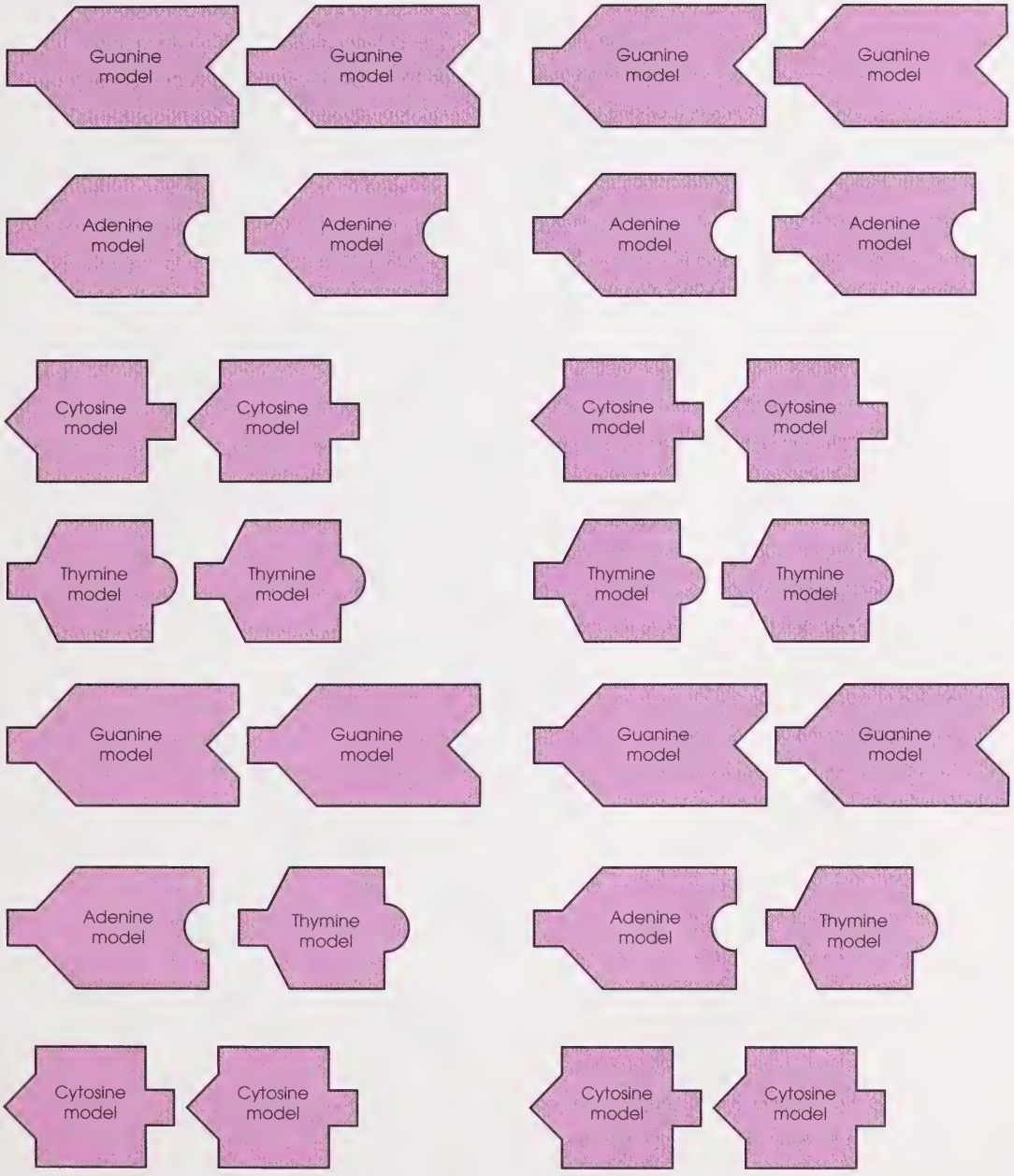
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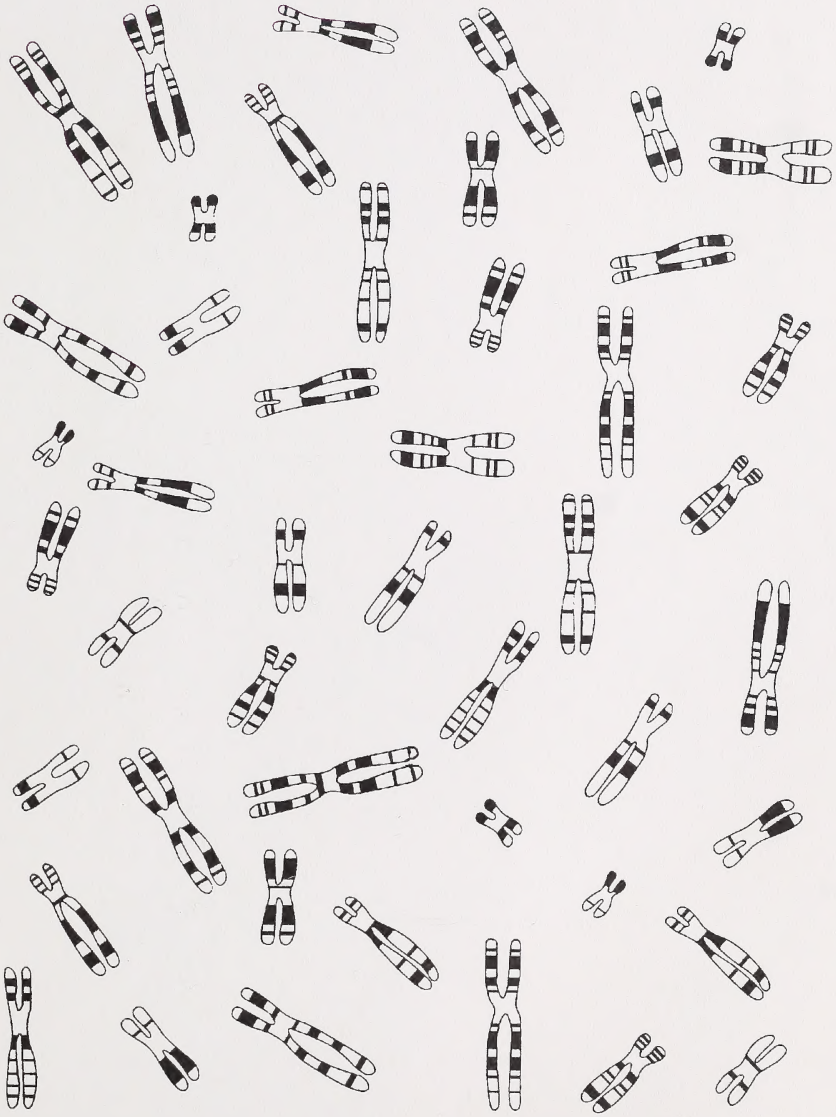
Individual A Karyotype



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